CENTRAL AREA SYSTEMS STUDY

Volume II

MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

De Leuw, Cather & Company
Consulting Engineers

CENTRAL AREA SYSTEMS STUDY

Volume II

MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

The preparation of this report has been financed in part through a grant from the U.S. Department of Transportation, Urban Mass Transportation Administration, under the Urban Mass Transportation Act of 1964, as amended.

De Leuw, Cather & Company
Consulting Engineers

PARTICIPATING PLANNING AGENCIES AND UNITS OF LOCAL GOVERNMENT

Massachusetts Bay Transportation Authority (MBTA)

Massachusetts Department of Public Works (MDPW)

Massachusetts Department of Commerce and Development (MDCD)

Metropolitan Area Planning Council (MAPC)

Eastern Massachusetts Regional Planning Project (EMRPP)

Boston Redevelopment Authority (BRA)

City of Boston
City of Cambridge
City of Newton
Town of Brookline
Town of Framingham
Town of Natick
Town of Needham
Town of Watertown
Town of Wellesley
Town of Weston

LEGEND

- SYSTEM I
- SYSTEM II
- SYSTEM III
- OTHER TRANSIT LINES

TRANSIT SYSTEMS
IN THE
CENTRAL AREA

DE LEUW, CATHER & COMPANY
ENGINEERS
CHICAGO NEW YORK PHILADELPHIA TORONTO OKLAHOMA CITY SAN FRANCISCO
24 SCHOOL STREET
BOSTON, MASSACHUSETTS 02108
AREA CODE 617 - TELEPHONE 523-4001

OUR REF. 1811-00

June 15, 1971

Mr. Walworth B. Williams, Project Manager
Central Area Systems Study
Massachusetts Bay Transportation Authority
500 Arborway
Boston, Massachusetts 02130

Dear Mr. Williams:

Contracts CS-003 and CS-005

In accordance with the terms of the designated contracts, we submit herewith our engineering report. This consists of two volumes on preliminary studies of physical feasibility and estimated cost of both the basic Central Area Systems and the Western Corridor studies.

Subsequent to commencement of work on this assignment in September 1968, there has been an appreciable redefinition of the basic scope of services as originally stated. Furthermore, the engineering solutions reported on herein were developed on the basis of economic and political considerations and Authority policies prevailing in 1969. Construction cost estimates were based on prices and wages prevailing in 1970. With these clarifications, the systems analysis approach using staged construction, which was adopted by DCCO early in the study, is deemed to provide sufficient flexibility to assure validity of the basic recommendations.

The scope of work stipulated in the contracts included four major areas of investigation and a minimum of eighteen specific study tasks. The effort expended on each of the latter varied with the problems encountered and the opportunities uncovered as the project progressed. These detailed engineering investigations and analyses of specific problems should be of substantial assistance in all future improvements of the Central Subway System.

Early in the study, after discussions with Authority staff, we were directed to assume that a new low-platform lightweight vehicle would

be designed by the Authority. Accordingly, in developing our System III Concept (conversion of the existing Central Subway to high-platform operation), we gave only limited consideration to use of an articulated vehicle which would have dual platform height capability. The operating characteristics and estimated costs would be significantly different if the latter type of equipment were to be considered in System III.

Our conclusions and recommendations are set forth in detail in the report. They may be summarized as follows:

(a) It is imperative that an immediate action program be instituted to improve reliability and quality of service on the entire Green Line.

(b) Additional planning should be started promptly toward ultimate improvements in the Central Subway and on the Riverside Line.

(c) It should be anticipated that the Riverside Line will ultimately have to be extended beyond its present terminus. Definitive steps should be taken, therefore, to reserve the existing railroad right-of-way and to contemplate integration of such an extension in future master planning.

With increasing awareness of the general public and of elected officials of the need to make maximum use of existing facilities to effect an adequate balanced transportation network in the Boston area, the vital role that could be played by the existing Green Line System should be fully exploited.

We sincerely appreciate the fine cooperation and assistance extended by all branches and departments of the Authority's staff during the study. We also express our gratitude for your own constructive assistance through the engagement.

Very truly yours,

DE LEUW, CATHER & COMPANY

R B Richards

R. B. Richards
President

TABLE OF CONTENTS

Chapter 1
SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS 1- 1
Central Area Alternatives 1- 2
Immediate Action Program 1- 4
Long-Range Planning 1- 4
Recommended System 1- 7
Western Corridor Alternatives 1- 8
Travel Analysis 1-11
Economic Analyses 1-13
Estimated Capital Costs 1-16
Costs 1-17
Comparative Analyses of Systems 1-18

Chapter 2
THE PROJECT 2- 1
Historical Development of Transit in the Study Area 2- 2
The Central Area 2- 4
Existing Transit Lines 2- 4
Existing Traffic 2- 8
Other Modes of Public Transportation 2-10
Deficiencies in the Existing Transit System 2-12
Objectives of the Engineering Studies 2-13
Scope and Development of Study 2-13

Chapter 3
IMMEDIATE ACTION PROGRAM 3- 1
Objectives 3- 2
Recommended Route Operations 3- 2
Rolling Stock 3- 3
Track and Roadbed on the Riverside Line 3- 6
Traction Power 3-10
Signals and Communications 3-11
Stations and Fare Collection 3-20
Vehicle Support Facilities 3-21
Anticipated Benefits and Limitations 3-22
Estimated Capital Costs 3-23

Chapter 4
SYSTEMS I, II AND III 4- 1
Systems Objectives 4- 3
System I 4- 4
Description of Route 4- 4
Description of Improvements 4- 9
Anticipated Benefits and Limitations 4-25

System II 4-34
Description of Route 4-34
Description of Improvements 4-39
Anticipated Benefits and Limitations 4-50
System III 4-55
Description of Routes 4-55
Description of Improvements 4-60
Anticipated Benefits and Limitations 4-70

Chapter 5
ALTERNATIVES STUDIED 5- 1
Operational Objectives 5- 2
Riverside Line Alternative Routes 5- 2
Connections Between Green and Blue Lines 5-11
Interconnections to Proposed Orange Line in Vicinity of Back Bay Station 5-16
North Station Alternatives 5-19
Extension of Huntington Avenue Subway to I-95 5-20
Huntington Avenue Subway Extension to I-695 5-22
Clearance Study 5-22
Rolling Stock 5-28

Chapter 6
WESTERN CORRIDOR 6- 1
Recommendations 6- 3
Objectives 6- 4
Route Description 6- 5
Staged Improvements - System A 6- 6
Description of Stage 1 Improvements 6- 8
Description of Stage 2 Improvements 6-13
System B 6-18
Western Corridor Alternatives 6-21
Benefits and Limitations 6-26

Chapter 7
ESTIMATED CAPITAL COSTS 7- 1
System I 7- 5
System II 7-11
System III 7-17
Western Corridor 7-23

BIBLIOGRAPHY

APPENDICES
Appendix A - Design Criteria ..... ap- 2
Appendix B - Architectural Design ..... ap- 6
Appendix C - Structural Design ..... ap- 8

Appendix D - Mechanical Facilities in Proposed Subways ap-11
Appendix E - Traction Power Study ap-14
Appendix F - Signal Data ap-43

LIST OF FIGURES

Figure		Page
Frontispiece	Transit Systems in the Central Area	
1- 1	Daily Inbound Transit Passengers - Riverside Line Near Fenway	1- 5
1- 2	System II	1- 6
1- 3	Daily Downtown Travel Time Saved on Each Transit Line	1-14
1- 4	Total Daily Downtown Travel Time Saved on All MBTA Lines	1-15
2- 1	Existing Transit Routes	2- 3
2- 2	Existing Transit Routes in Central Area	2- 5
2- 3	One-Way Daily Transit Riders - 1963	2- 9
2- 4	Proposed Transit Routes in the Western Corridor	2-11
3- 1	The Green Lines System in Stage 1	3- 4
3- 2	Proposed Track on Ballast	3- 9
3- 3	Speed Control Criteria	3-14
4- 1	System I - Stage 2 Proposals	4- 6
4- 2	System I - Stage 3 Proposals	4- 7
4- 3	System I - Stage 4 Proposals	4- 8
4- 4	Temporary Incline at Back Bay Station System I, Stage 2	4-11
4- 5	Proposed Track Fastened to Concrete Invert	4-23
4- 6	Estimated One-Way Daily Transit Riders in 1990 System I	4-26
4- 7	Estimated Daily Station Entries in 1990 System I	4-28
4- 8	Estimated Daily Transfers in 1990 - System I Park Street Station	4-29
4- 9	Estimated Daily Transfers in 1990 - System I Back Bay Station	4-29

Figure		Page
4-10	Estimated Daily Transfers in 1990 - System I Government Center Station	4-30
4-11	Estimated Daily Transfers in 1990 - System I Washington Station	4-31
4-12	Estimated One-Way Daily Transit Riders in 1990 - Existing System with Stage 1 Improvements Only	4-32
4-13	Estimated Daily Station Entries in 1990 - Existing System with Stage 1 Improvements Only	4-33
4-14	System II - Stage 2 Proposals	4-35
4-15	System II - Stage 3 Proposals	4-37
4-16	System II - Stage 4 Proposals	4-38
4-17	Soil Profile Along Proposed Subway	4-40
4-18	Extent of Filled Areas in Boston Peninsula	4-42
4-19	Interior View - Transit Station Above Ground	4-45
4-20	Exterior View - Transit Station Above Ground	4-46
4-21	Estimated One-Way Daily Transit Riders in 1990 System II	4-51
4-22	Estimated Daily Station Entries in 1990 System II	4-52
4-23	Estimated Daily Transfers in 1990 - System II Park Street Station	4-53
4-24	Estimated Daily Transfers in 1990 - System II Back Bay Station	4-53
4-25	Estimated Daily Transfers in 1990 - System II Government Center Station	4-54
4-26	Estimated Daily Transfers in 1990 - System II North Station	4-54
4-27	Estimated Daily Transfers in 1990 - System II Washington Station	4-54
4-28	System III - Stage 2 Proposals	4-57
4-29	System III - Stage 3 Proposals	4-58
4-30	System III - Stage 4 Proposals	4-59
4-31	Estimated One-Way Daily Transit Riders in 1990 System III	4-71
4-32	Estimated Daily Station Entries in 1990 System III	4-72
4-33	Estimated Daily Transfers in 1990 - System III Park Street Station	4-73
4-34	Estimated Daily Transfers in 1990 - System III Back Bay Station	4-73
4-35	Estimated Daily Transfers in 1990 - System III Government Center Station	4-74
4-36	Estimated Daily Transfers in 1990 - System III Washington Station	4-74

Figure		Page
5- 1	Tremont Street Alternatives	5- 5
5- 2	Stuart Street Alternatives	5- 8
5- 3	Columbus Avenue Alternatives	5-10
5- 4	Beacon Hill Tunnel Alternatives	5-12
5- 5	Government Center Loop Subway	5-15
5- 6	Connection of Riverside Line to Orange Line	5-18
5- 7	Huntington Avenue Subway Extension to I-95	5-21
5- 8	Huntington Avenue Subway Extension to I-695	5-23
5- 9	Typical Clearance Diagram	5-24
5-10	Eight Car Template	5-24
5-11	Lateral Adjustment Due to Superelevation	5-26
5-12	Displacement Due to Track Curvature	5-26
5-13	Speed-Time Curves	5-32
5-14	Distance Time Curves	5-32
5-15	Comparison of Elapsed Time Using Various Transit Cars	5-33
5-16	Running Times Between Riverside and Central Area	5-34
6- 1	Western Corridor - Study Areas and Systems	6- 6
6- 2	System A - Stage 1 Proposals	6- 7
6- 3	System A - Stage 2 Proposals	6-14
6- 4	Running Times Between Framingham and Central Area	6-26
7- 1	Construction Cost Index	7- 4
7- 2	Segments of Stage 1 - Systems I, II and III	7- 4
7- 3	Segments of System I	7- 5
7- 4	Segments of System II	7-11
7- 5	Segments of System III	7-17
7- 6	Segments of Proposed Routes in the Western Corridor	7-23
C- 1	Stages in Cut-and-Cover Construction	ap- 9
F- 1	Existing Signals at Copley Junction	ap-43
F- 2	Proposed Signal Modifications at Copley Junction	ap-44
F- 3	Segregation of Road and Rail Tracks at Major Junctions	ap-50
F- 4	Major Road Intersection	ap-51
F- 5	Minimum Warning Protection at Intersection	ap-52
F- 6	Minimum Theoretical Headway of No. 6 Car in Central Subway	ap-55

Tremont Street Mall

Chapter 1
SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

Chapter 1

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

Volume II of the Central Area Systems Study Report is concerned with the physical feasibility and cost of alternative improvements for the Central Area subway system and for possible extensions of rail transit service to the Needham and Framingham areas.

The development and evaluation of improvement alternatives was authorized by the Massachusetts Bay Transportation Authority under the terms of the basic Federal-aid application for the Central Area Systems Study. Engineering investigations were conducted by De Leuw, Cather & Company, consultants to the Authority. The results reported in Volume II reflect the Consultant's investigation, analysis and evaluation of engineering data relevant to the Study.

CENTRAL AREA ALTERNATIVES

Considerable discussion and controversy has developed over the years regarding the nature and scope of the problems inherent in the operation of the existing Central Subway system. Early in the study of specific problems, two factors became apparent:

(1) Isolated problems could not be resolved without evaluating their effects on the overall system; and

(2) Because of the range of alternative improvement programs and the broad interrelationships involved, staged construction would be required to permit progressive financing of new projects while allowing continuous operation of existing facilities.

Following investigation of numerous alternatives, three comparable systems of improvements were developed to solve identifiable problems. Each system was based on a different general assumption:

System I assumed that the former Boston & Albany Railroad right of way from Fenway Park to South Station would become available for MBTA operations.

System II assumed that the B&A Railroad right of way would not become available for MBTA operations.

System III assumed that the existing Riverside Line and Boylston Street Subway would be converted to high platform rapid transit-type operation.

The three systems are compared in the following table.

CASS SYSTEMS CONCEPT COMPARISON

	SYSTEM I	SYSTEM II	SYSTEM III
CONCEPTS	B&A RIGHT OF WAY AVAILABLE FOR MBTA OPERATIONS	B&A RIGHT OF WAY NOT AVAILABLE FOR MBTA OPERATIONS	CENTRAL SUBWAY CONVERTED TO HIGH PLATFORM RAPID TRANSIT OPERATIONS
STAGE 1	1. Watertown Line discontinued. Modify Arborway Line. 2. Upgrade existing Riverside Line and Central Subway. 3. Acquire new low-level cars. 4. Improve vehicle support capability.		
STAGE 2	1. Acquire B&A right of way. 2. Construct connection at Fenway and new stations on B&A right of way to South Station. 3. Route Riverside Line to South Station.	1. Extend Huntington Avenue Subway to Back Bay Station. 2. Construct new low-platform station at South Station. 3. Initiate Brigham Circle to South Station service. Eliminate Copley Junction for revenue service.	1. Extend Huntington Avenue Subway to B&A tracks at Back Bay. 2. Construct new low-platform stations at Back Bay and South Station. 3. Initiate Brigham Circle to South Station service. Eliminate Copley Junction for revenue service.
STAGE 3	1. Construct high-level stations Riverside to South Station. 2. Develop high-level vehicle support capability at Riverside. 3. Acquire high-level cars and initiate Riverside to South Station service. 4. Construct new terminal facility in vicinity of Canal Street. Remove elevated structure.	1. Extend Huntington Avenue Subway from Northeastern to Brookline Village. 2. Construct high-level stations Riverside to South Station. 3. Develop high-level vehicle support capability at Riverside. 4. Acquire high-level cars and initiate Riverside to South Station service. 5. Construct new terminal facility in vicinity of Canal Street. Remove elevated structure.	1. Construct new subway east of Arlington Station to Bowdoin Station via Boston Common. 2. Construct new connection from Tremont Street tunnel to B&A right of way. 3. Develop transfer facilities at Fenway and Kenmore. 4. Develop high and low-level vehicle support capability at Riverside. 5. Convert Riverside line and Boylston Street Subway stations to high-level platforms. 6. Acquire high-level cars and initiate service Riverside to Wonderland via Boston Common. 7. Construct new terminal facility in vicinity of Canal Street. Remove elevated structure. 8. Initiate low-level service Brigham Circle to North Station via Tremont Street Subway.
STAGE 4	1. Construct new subway via Columbus Avenue and Boston Common to Bowdoin. 2. Initiate Riverside to Wonderland service. 3. Evaluate demand for South Station service.	1. Construct new subway via Columbus Avenue and Boston Common to Bowdoin. 2. Initiate Riverside to Wonderland service. 3. Evaluate demand for South Station service.	1. Construct subway connection Brigham Circle to Brookline Village. 2. Initiate low-level service, Brookline Village to North Station. 3. Evaluate demand for South Station service.

IMMEDIATE ACTION PROGRAM

Stage 1 improvements under all three systems would be identical, and would constitute the Immediate Action Program. The urgency of implementing this program has been recognized by the Authority; the program was incorporated in requests for additional bonding power to the Joint Committee on Transportation, in 1969 and 1970.

The most important recommendation is that the Authority acquire, as soon as possible, new rolling stock for the existing Riverside and Huntington Avenue Lines. It is also recommended that the existing Riverside and Central Subway physical plant be upgraded to permit full use of technological improvements incorporated in the new equipment. Major improvements are proposed in power, signals, communications, and track and roadbed. Improved vehicle support capabilities--including the development of new shops at Riverside Terminal--are recommended to assure proper maintenance and servicing of the new cars.

The Immediate Action Program would also incorporate the Authority's pending modifications to the Watertown and Arborway surface lines. These modifications have been proposed to alleviate difficulties resulting from transit operation mixed with general street traffic.

The Consultant concurs generally in the desirability of other specific improvements to the Green Line as proposed in the Authority's request for additional bonding power.

The recommended Immediate Action Program (Stage 1 of all alternative Central Area system improvements) is discussed in detail in Chapter 3 of this volume.

LONG-RANGE PLANNING

While it is apparent that prompt implementation of Stage 1 recommendations would result in significant improvements, these improvements would alleviate only the most critical operational problems. Physical limitations and basic operational characteristics of the existing system would preclude maintaining desirable levels of service as passenger volumes increased. Experience has shown that low-platform, limited-length trains have an hourly capacity of only 12,000 to 14,000 people per track whereas conventional high-platform, rapid transit-type equipment can carry 25,000 or more. Recent Authority experience with express bus operations from Riverside confirms that travel time reductions attract additional riders. The express buses will be satisfactory, however, only as long as highway traffic volumes remain well below capacity.

Review of traffic projections indicates that Stage 1 improvements would do little more than reverse the recent declining trend in passenger volumes which is deemed to be attributable to deteriorating service. A long-range improvement program is considered necessary to preclude problems in the future similar to the present operational deterioration of the Central Subway. Planning should define ultimate objectives and priorities while retaining sufficient flexibility for adjustment to future events. See Figure 1-1.

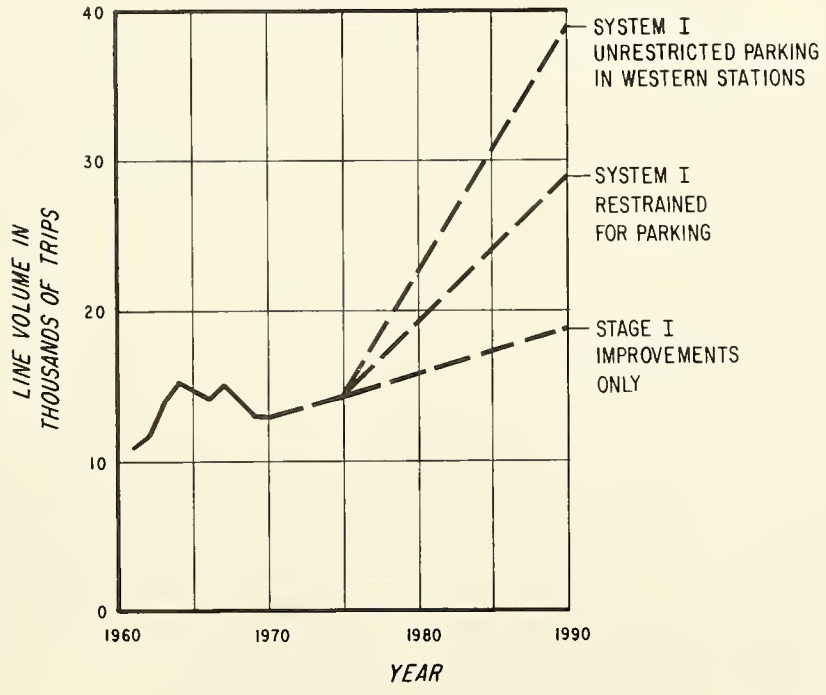


Figure 1-1

DAILY INBOUND TRANSIT PASSENGERS
RIVERSIDE LINE NEAR FENWAY

Analyses of passenger volume projections indicate that implementation of any of the three alternative systems studied would result in a significant increase in number of riders. While unpredictable factors might permit comparable results with some other combination of improvements, System II appears to be the best solution to the overall problem as currently defined. It is recommended, therefore, that the Authority establish a long-range program to furnish high-level rapid transit-type service from the Riverside-Western Corridor to the Northeast Corridor by adopting System II. See Figure 1-2.

Figure 1-2

SYSTEM II

Since the Immediate Action Program developed as Stage 1 would be identical with all systems, its early implementation would in no way restrict the flexibility inherent in the systems approach. The time required to implement the successive stages in the recommended System II should provide ample opportunity to evaluate each step as completed and to re-evaluate primary factors as a guide to succeeding steps.

RECOMMENDED SYSTEM

The recommended System II would reduce the number of car movements in the Central Subway and improve service on the Highland Branch by diverting the Riverside Line at Brookline Village to Brigham Circle and then via Huntington Avenue to Back Bay. A new connection via Columbus Avenue and under Boston Common would improve spinal area distribution and provide for through service by means of the interconnection with the Blue Line at Bowdoin Station. System II assumes the implementation of current planning for the relocation of the Orange Line through South Cove Tunnel and Back Bay. The total estimated construction cost for the complete System II is $198,000,000 (in 1970 dollars).

While Stage 1 would provide substantial improvement of operating conditions and speeds in the existing Central Subway, it would not effectively eliminate any of the basic problems. At Copley Junction, the outbound Huntington Avenue Line cars cross the inbound trains of all other Green Lines at grade. The conflicting movements would be eliminated in Stage 2 by rerouting the Huntington Avenue Line to Back Bay or South Station. This would be accomplished by constructing a new connection from the existing Huntington Avenue Subway just north of Prudential Station to a new Green Line Back Bay Station directly under the proposed Orange Line Station. Assuming that the relocated Orange Line through Back Bay Station was not in operation, the rerouted Huntington Avenue Line would come to the surface, via a temporary incline, within the former New York, New Haven and Hartford Railroad right of way in which it would continue into South Station. Since no additional changes in the Huntington Avenue Line, other than those previously recommended in Stage 1, are contemplated, low-level equipment service from Brigham Circle to Back Bay or South Station could be initiated upon completion of construction.

During this stage the Riverside, Beacon Street and Commonwealth Avenue Lines would continue to operate in the Central Subway, terminating at Lechmere and Government Center as they do now. The physical facilities at Copley Junction should be retained for off-peak period maintenance movements. The conversion of the low-level shop facilities developed at Riverside Terminal in Stage 1 to accommodate high-level equipment should be initiated in Stage 2. The total estimated cost of the proposed Stage 2 improvements is $25,900,000 (at 1970 cost levels).

Stage 3 of System II would permit high-platform rapid transit operation from Riverside to Back Bay or South Station via Huntington Avenue. From Riverside to Brookline Village, new high-level platform stations would be constructed while existing low-level operations

were continued. A new subway would be constructed from Brookline Village through Brigham Circle and under Huntington Avenue to connect with the existing subway at Northeastern University, with new stations at Brigham Circle and Northeastern. The remaining existing subway stations would be converted to high platforms under traffic. Also, the conversion of the Riverside yard and shop to accommodate high-level equipment would be completed.

The need for some type of shuttle service from Brookline Village to Kenmore Square via existing Highland Branch right of way should be evaluated.

While the program allows some flexibility in timing, elimination of the Green Line Causeway Street elevated structure is contemplated in Stage 3. This could be accomplished by constructing the new Green Line North Station and underground car storage area. This facility would be integrated with the new Orange Line Station and a possible surface bus-to-rail transfer area built between Canal and Causeway Streets. The total estimated cost of proposed Stage 3 improvements is $91,400,000 (at 1970 cost levels).

The fourth and final stage of System II would involve construction of a new subway connection from Back Bay via Columbus Avenue, Boston Common and Beacon Hill to the existing Blue Line Station at Bowdoin. New stations would be provided at Stuart-Eliot Streets and at Park Street. Not only would the Green (Riverside) and Blue (East Boston) Lines be interconnected, but the transfer capability of the entire downtown transit network would be improved by virtue of the interfaces at Back Bay and Park Street Stations. The Beacon Street and Commonwealth Avenue Lines would continue to operate in the improved Central Subway. The total estimated cost of the proposed Stage 4 improvements is $59,500,000 (at 1970 cost levels).

A detailed description of improvements recommended for Stages 2, 3 and 4 will be found in Chapter 4 of this volume. Volume III of this report contains complete plans for each of the systems. The specific limits of each stage have been chosen not only on the basis of economic considerations and the need to maintain service, but also to provide definitive check points for the evaluation of improvements implemented and the integration of previously unpredictable factors.

WESTERN CORRIDOR ALTERNATIVES

In addition to studies relating to the Central Area System, the Consultant was asked to investigate the engineering feasibility and cost of extending MBTA rail service to the Needham and Framingham areas. Each of these areas would be served by a separate extension integrated with the improved Riverside Line.

Two alternative systems were developed and evaluated:

System A assumed that the former B&A Railroad right of way from Riverside to South Station would not become available for MBTA operations, and that the Penn Central Transportation Company would continue to use the right of way from Framingham to Riverside as at present.

System B assumed that the Penn Central would discontinue passenger service east of Framingham and freight service east of Wellesley, and that the unused portion of the former B&A Railroad right of way would become available for MBTA operations.

Western Corridor alternatives are further discussed in Chapter 6.

The Western Corridor alternatives were not tied to a specific stage of the basic CASS plans as they were not directly dependent thereon. It would appear desirable, however, to improve the Riverside Line to the point that high platform rapid transit operations were possible before proceeding with the Framingham-Natick extension.

From Framingham to Riverside the existing railroad right of way at one time accommodated four tracks. At the present time only the two northerly tracks remain; however, the railroad company has retained the property. From Riverside to the South Station area, the construction of the Massachusetts Turnpike Extension resulted in reduction of the railroad facilities to two tracks located on an easement from the Turnpike Authority. While elimination of railroad operations throughout this area would facilitate rapid transit operations, this assumption does not presently appear realistic. Consistent with this factor and the previous recommendation for the basic Central Area system, the Authority should establish the long-range goal of providing high-platform rail rapid transit service from Framingham-Natick and Needham Heights by the adoption of System A. Several potentially attractive alternatives have been developed for portions of this system and are discussed later in this chapter.

Stage 1 of System A would provide essentially for initiation of service to Needham Heights and the acquisition of right of way for future establishment of service to the Framingham-Natick area. Available traffic projections have all been predicated on relocation and extension of the Orange Line to at least V.F.W. Parkway and in some cases to Needham Junction. Engineering studies have indicated that a grade-separated branch of the Riverside Line could be extended very readily from Cooks Junction to Needham Heights by using a portion of the former New York, New Haven and Hartford Railroad right of way. This extension could be accomplished with a minimum of disturbance to the existing freight operations at a 1970 estimated cost of $14,400,000 and

could be in service by the time the new low-level equipment (No. 6 car) was available. Grade separation structures, both railroad and transit, would be constructed over Chestnut, Gould and Webster Streets, the Charles River, and Route 128. New low-platform stations with provisions for bus transfers and both long- and short-term parking would be constructed at Newton Upper Falls and West Street-Needham Heights. Since the extension of low-platform rail service to Needham Heights can be expeditiously accomplished at a reasonable cost and the current time schedule for Orange Line extensions are indefinite, its prompt implementation has been recommended. Before proceeding, however, with the conversion of this extension to high-platform rapid transit-type service, as envisioned in Stage 2, a definitive evaluation of passenger loadings and the ultimate Orange Line construction schedule (and terminal location) should be made. At the same time, definitive steps would be taken to acquire the currently unused portion of the former B & A right of way between Framingham and Riverside from the Penn Central.

Stage 2 of System A studies were predicated upon two assumptions --that the Authority would acquire at least the currently unused portion of the railroad right of way from the Penn Central; and that ultimate construction would permit the use of Red Line (No. 5 car) equipment. Since both assumptions are conservative, it is possible that high-platform, rapid transit-type service might be extended to the Framingham-Natick area more quickly and economically than the estimated $37,000,000. This possibility is discussed in detail in this chapter section entitled The Comparative Analyses of Systems and in Chapter 6.

Placement of two rapid transit tracks in the area formerly occupied by two railroad tracks on the B & A right of way would require greater clearances than currently are available. Since the rapid transit tracks would be electrified, it would be necessary to provide space for the power supply and distribution system and to separate the two rights of way by a fence. It would also be necessary to reconstruct or extend most of the existing grade-separation structures spanning the right of way. While the reconstruction or extension of these structures would result in improvement to the local street networks, cost estimates did not assume local participation since this would be a matter for negotiation by the Authority.

New high-platform stations would be constructed at Wellesley Farms, Wellesley, Natick, West Natick and Framingham. The proposed station locations were carefully chosen to be compatible with existing local travel patterns and were integrated with the arterial street networks. All stations have provisions for bus transfer movements and short- and long-term parking. The possibility of locating the western terminal closer to downtown Framingham was investigated. However, definite planning appeared impractical at this time because of uncer-

tainties regarding the elimination of existing grade crossings west of the proposed terminal. As community problems are resolved by local interests and the State Department of Public Works, the studies initiated under CASS should be reviewed and evaluated.

TRAVEL ANALYSIS

Basic travel projections through the year 1990 for the various alternatives under study were supplied by the Authority after major engineering investigations had been substantially completed. The transit-ridership forecasts evolved directly from forecasts of long-range regional land use and trip generation distribution developed for the Boston Metropolitan Area Transportation Study (BMATS), formerly the Eastern Massachusetts Regional Planning Project (EMRPP). Computerized techniques, developed by others, for analyzing downtown and comparative corridor distribution were applied to the total person-trip tables to test the alternative systems. Detailed descriptions of the traffic analysis techniques are contained in reports by others.

Existing Traffic

The Green Line is the most extensive interconnected network in the entire MBTA system, and the oldest in terms of physical facilities and operational equipment. As the only rail rapid transit line extending to circumferential Route 128, it must serve peak-hour commuters interested in prompt, dependable passage to the Boston Central Area as well as riders to entertainment, educational, and medical areas concentrated in the Prudential Center-Government Center spine. Combining these functions using old low-level, PCC-type streetcars designed primarily for stop-and-go operation can only result in less than adequate service. Despite functional and operational handicaps, the Central Subway section from Copley to Park Street Station in March of 1969 provided a peak-hour service of 64.5 trains, or 168 cars. Much of the Green Line ridership may be considered captive patronage. The comparatively high-density residential development along the existing routes and the limited availability of alternative forms of public transportation offer residents little choice of transit modes. This is illustrated by the fact that the last general fare increase in 1968 caused only a temporary decline in total ridership, which was quickly restored. Despite the poor travel times and inefficient equipment, more than 150,000 passengers per day continue to use the Green Line System.

At the present time, potential patrons originating west of the terminal at Riverside have a multiplicity of choices for core-area trips. Limited railroad commuter service still is available, although schedules have been substantially reduced. In addition, the expanded highway network has not yet reached a level of saturation, even in peak

periods, sufficient to delay the individual motorist or discourage the use of buses. However, constantly increasing subsidies are being required to maintain commuter rail service, and public demand is growing for balanced transportation networks to minimize detrimental effects on metropolitan environment. Therefore, it appears that improved mass transit facilities ultimately will be needed in the Western Corridor. As a step in that direction, the Authority recently inaugurated express bus service from Watertown and Riverside to downtown Boston via the Massachusetts Turnpike.

Future Travel Patterns

Transit ridership estimates based on the results of corridor studies indicated that there would be significant increases in corridor-to-downtown and corridor-to-corridor (through downtown) transit trips. The EMRPP Recommended Highway and Transit Plan, which developed the basic traffic projections, predicted that from 1963 to 1990 the regional population would increase by 34 percent, employment by 39 percent, transit travel by 45 percent and vehicle miles of travel by 100 percent. These projections assumed the completion of the proposed highway network (including the Innerbelt and Middle Circumferential Highways), the completion of the currently approved MBTA extensions and improvements, and the continuation of both rail and express bus commuter service.

Such ridership increases would have appreciable impacts on the downtown system and would compound the congestion problems already experienced in the Central Subway. Daily rapid transit trips to downtown Boston totaled 170,000 in 1963 compared with a forecast total of 229,000 in 1990--a 35 percent increase. In 1990, levels of downtown transit system activities (boardings, alightments and transfers) are expected to exceed 1963 levels by 60 percent. Corridor-to-corridor transit trips in 1990 are expected to exceed 1963 volumes by nearly 85 percent. Improvements in the downtown system should be accomplished to accommodate this anticipated growth.

A comparison of actual 1963 volumes with 1990 projected volumes indicated substantial growth in boardings at the four outermost stations of the Riverside Line, with a particularly high parking demand at the Riverside terminal. In reviewing traffic projections, the primary question pertaining to the proposed Western Corridor extension beyond Riverside appeared to be not how many additional riders would it attract, but how would the demand, generated by population growth alone, be satisfied. Without the Framingham-Natick extension, it was estimated that, by 1990, 5000 parking spaces would be required between Reservoir and Riverside, and an additional 7400 parking spaces at Riverside. Sufficient land area is not available at the stations to develop the necessary parking capacity. The use of parking structures

to overcome land limitations would not be feasible because peak-period traffic volumes would be considerably greater than the capacity of supporting arterial street and freeway networks. Thus, the extension beyond Riverside would produce increases in line ridership by providing parking space sufficient to satisfy the significant parking demand.

ECONOMIC ANALYSES

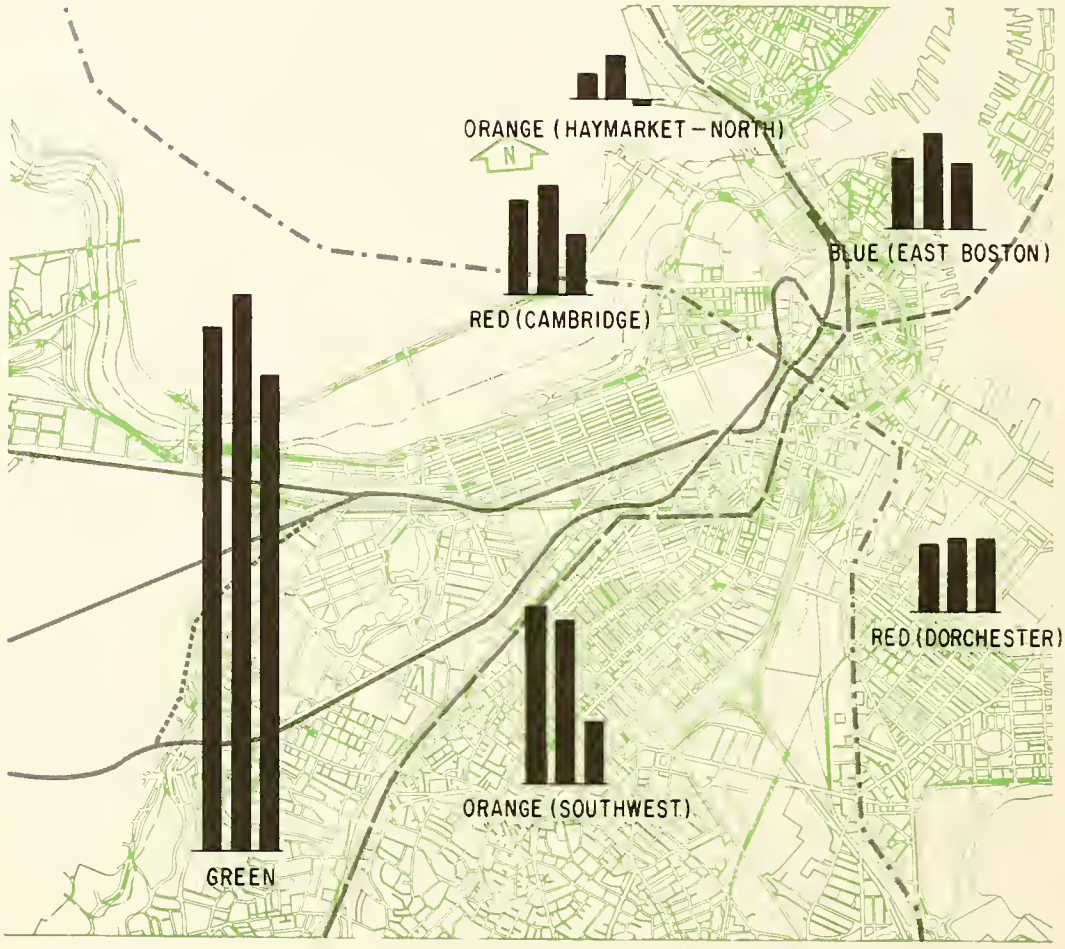
Economic benefits accruing from major investments and/or improvements in transit systems may take many forms. Direct benefits which are observable and measurable include shorter travel time, improved distribution in the core area, more balanced line loadings, elimination of forced transfers, improved transfer facilities, more reliable service, and lower operating and maintenance expenses. In addition, there are often benefits which are not directly measurable or quantifiable such as more esthetic environment, more comfortable vehicles, and reductions in the load on or elimination of the need for expanding other transportation facilities.

The Authority's long-range improvement program has not yet fully considered the existing Green Line and Blue Line systems. One reason has apparently been the multiplicity of possible improvements deserving consideration. Another factor has been the dramatic revitalization and expansion of the core area of Boston within the last ten years, brought about both by public renewal and by privately financed projects. While these and other developments in the future may produce problems that cannot be foreseen at present, the continuing increase in demands on existing transportation facilities, despite deteriorating service, makes it advisable to establish basic goals at an early date.

It is recognized that other Authority projects have prior claims on the limited funds currently available. There are clear indications, however, that growing public interest in better mass transportation facilities will soon result in additional funding by the Federal government. If the basic planning goals developed by this study are accepted and adopted by the Authority, an important step toward meeting both current and future transportation needs will have been taken by making the Authority eligible for such funds.

Direct Benefits

The viewpoints of the Authority staff and the Engineer Consultant differ significantly as to what basic level of service should be provided on the Riverside Line in the future. While development of long-range policy by the Authority is strongly influenced by prior master plan commitments and restrictive economic considerations, the identifiable direct benefits to the public appear so great that the Consultant recommends that early attention be given to the ultimate Riverside Line proposals.



SCALE
SYSTEMS
I II III

100,000

50,000

0

PASSENGER – MINUTES
SAVED PER DAY

LEGEND

- GREEN LINE
- BLUE LINE
- ORANGE LINE
- RED LINE
- GREEN LINE SHUTTLE

Figure 1-3

DAILY DOWNTOWN TRAVEL TIME
SAVED ON EACH TRANSIT LINE

Systems I, II & III compared
with implementing Stage I only

Specifically, the population growth alone in the area served by the existing Green Line (including the Western Corridor) indicates that transit ridership will increase by about 45 percent by 1990. The implementation of Stage 1 would further cause transit ridership to increase by 85 percent, it was estimated, while System II implementation would produce a 360 percent increase in number of transit riders originating west of Reservoir Station. These projections assume construction of the entire proposed highway network (including the Inner and Mid Circumferential Belts), continuation of existing railroad commuter and express bus services, and extension of the Orange Line to the vicinity of Route 128. Accordingly, these estimates are conservative in that they do not anticipate any additional gain in transit riders resulting from discontinuance of railroad commuter service or failure to complete the assumed highway system. The Recommended Immediate Action Program (Stage 1) would not be capable of meeting this increased demand. Unless the Authority begins planning now to provide fast, reliable, comfortable service with sufficient capacity, a substantial number of potential riders will refrain from using public transit and will, instead, contribute to highway congestion.

The need for capital improvements on the Green Line beyond Stage 1 can be further demonstrated by considering the effect of the proposed improvements on travel times.

Figure 1-3 shows that the downtown travel time savings for Green Line passengers based on System II implementation would be 360,000 passenger-minutes per day or 1,800,000 passenger-hours per year.

Blue Line downtown travel time savings would similarly yield another 300,000 passenger-hours annually. Figure 1-4 indicates that the total downtown travel time saved on all the MBTA lines would be over 11,000 passenger-hours per day or 3,300,000 passenger-hours annually, compared with implementing Stage 1 only.

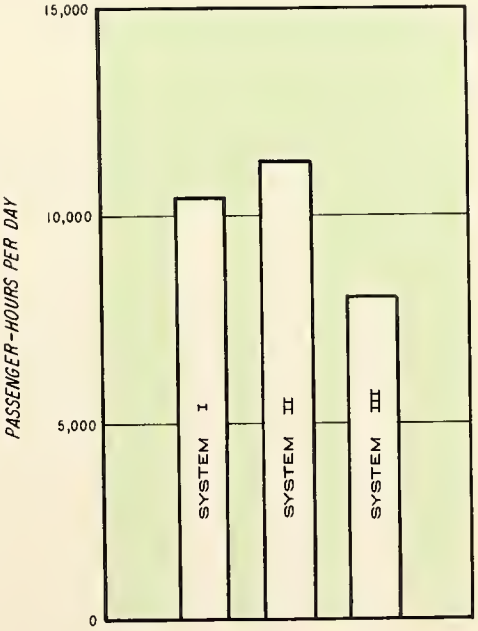


Figure 1-4

TOTAL DAILY DOWNTOWN TRAVEL TIME SAVED ON ALL MBTA LINES
Compared with implementing Stage 1 only

Other direct benefits to the transit user, commuter and business community include:

- Reduced cost of automobile operation, parking and insurance.
- Reduced need for parking facilities and second automobiles for commuting.
- Savings in travel time for motorists.
- Reduced number of accidents.
- Savings to the trucking industry and its clients.

Indirect Benefits

Indirect benefits, although not quite as easily quantified, are important and should be included in evaluating the Systems. Some of the indirect benefits that would be realized include increases in construction activities and property values which would broaden the tax base; reductions in highway construction costs, and in air and noise pollution; improved mobility for the aged, young, unemployed and handicapped; better access to centers of education, recreation, employment, commerce and medical services; preservation of established communities; and provision of comfortable, fast and dependable service for transit users.

ESTIMATED CAPITAL COSTS

Each system was divided into a number of segments which represented the extent of a particular type of construction such as tunneling or cut-and-cover, or the terminal point of work to be performed in a particular stage.

The cost estimates cover all materials, labor and equipment; engineering and inspection of construction; track and roadbed; traction power distribution; signals and communications; and contingencies.

Cost estimates were prepared in 1969 and adjusted for inflationary trends to establish 1970 as the base year.

Major items omitted from the cost estimates are:

- Acquisition and clearing of rights of way.
- Underpinning of structures adjacent to the subways.
- Purchase of rolling stock.

- MBTA's administrative and engineering expenses.
- MBTA's additional maintenance and operating expenses during construction.
- Support or relocation of privately-owned utilities.
- Clearance improvements in the Central Subway.
- Civil engineering improvements to surface portions of the Green Lines.
- Car-borne signal and communications equipment.
- Maintenance and repair facilities at Reservoir and Riverside.
- Central supervisory control equipment.

COSTS

A summary of capital costs based on suggested stage construction follows:

Central Area System	
System I - Stages 1 through 4	$137,000,000
System II - Stages 1 through 4	198,000,000
System III - Stages 1 through 4	180,200,000
Immediate Action Improvements (Included in System Totals) - Stage 1	21,200,000
Western Corridor	
Needham Extension	
Needham Heights to Cooks Junction	$ 14,400,000
Framingham Extension	
Framingham to Riverside - System A	37,000,000
Framingham to Fenway Park - System B (via Boston & Albany Railroad)	52,400,000

The summary and detail breakdown of the capital costs for Systems I, II and III and Western Corridor Extensions are presented in Chapter 7.

COMPARATIVE ANALYSES OF SYSTEMS

Central Area Systems

In the basic study, a critical element that influenced the development of the individual systems was the availability and potential use of the existing rail corridor from South Station to Fenway Park (former B & A Railroad right of way). As noted earlier, System I assumes that the MBTA could acquire or lease this railroad facility. Systems II and III attempt to develop alternative means of improving operations assuming that the railroad facilities could not be obtained by the MBTA.

Other primary criteria included recognition that the core area of Boston is expanding westward making it desirable to incorporate the Back Bay-Prudential Area into the system. It was also acknowledged that it would be desirable to expand existing distribution functions in the core area by providing alternative connections between Back Bay and Government Center. Such connections would also eliminate in-town terminals by through-routing the Blue and Green Lines. Several other considerations were evaluated during the system studies.

Some of the basic parameters imposed on all studies were as follows:

- Costs were estimated in sufficient detail and uniformly applied to reveal differences between systems.

- Alternative route locations were established and evaluated on the basis of available mapping and aerial photography and verified by field inspection.

- Soils profiles for the study routes were developed based on available subsurface information.

- Alternative station locations were evaluated on the basis of existing and future land use, historical travel patterns and area development as well as on existing and proposed highway and public transit routes.

- Existing MBTA design criteria and committed improvements and/or extensions were accepted.

- Traction power network design and costs were predicated on ultimate development of the appropriate system's concept.

- Signal and communications networks were developed to provide continuous, safe, positive control of all trains consistent with current Authority policies.

While there are basic differences in the three systems developed, there are also significant areas of similarity. In addition, it is recognized that the ultimate recommendation must include evaluation of other than engineering factors. Any of the systems could be implemented by the Authority, and any would immediately improve service and would have capacity to accommodate future demands.

It has been noted that the capital cost estimates in this portion of the report do not include any allowance for right of way acquisition; accordingly, apparent cost differentials might be substantially modified as a result of negotiation between the Authority and other agencies.

Failure to improve the existing system would lead to continued deterioration of service and increasing public dissatisfaction. Implementation of any of the alternative systems, on the other hand, would greatly raise the level of service and draw substantially increased patronage.

Objective analysis of the alternative systems requires evaluation of numerous factors including but not limited to:

- Effect on travel times.
- Estimated costs.
- Rider transfer capability and requirements.
- Frequency and dependability of service.
- Convenience, safety and comfort.
- Effects on the community and the environment.

Since the Authority's role is to transport people safely, comfortably, economically and expeditiously, any acceptable plan must be compatible with these objectives. Some of the more significant attributes of the various systems are tabulated below.

COMPARATIVE DATA ON ALTERNATIVE SYSTEMS

	System I	System II	System III
Capital Cost	$137,000,000	$198,000,000	$180,000,000
Additional ROW Requirements	B & A Railroad (Fenway to South Station)	Minor	Interference with B & A Railroad (Back Bay to South Station)
Travel Time Savings for Green-Blue Line Riders. (Passenger-Hours/day)	500	1,200	Base
Total System Daily Travel Time Savings (Passenger-Hours/day)	2,400	3,200	Base
Transfer Characteristics			
a) Beacon and Commonwealth Line Riders to Downtown	Not required	Not required	Forced
b) Number of Transfers to get to Any Other Line	One	One	Two
c) At Back Bay Station	Platform up to lobby and down to platform	Platform to platform	Not available from Blue-Green Line
d) Forced Blue Line to Green Line Transfers at Gov't Center	Eliminated	Eliminated	Eliminated
Number of Transferring Passengers			
a) At Washington Street Station (daily)	58,300	58,500	79,700
b) At State Street Station (daily)	35,300	35,300	46,900
Copley Junction Eliminated	No	Yes	Yes
Development Potential for Abutting Property	Good	Excellent	Poor
Inconvenience to Riders during Construction	Minimal	Tolerable	Excessive
Inconvenience to Community during Construction	Minimal	Annoying	Tolerable
Reduction in At-grade Street Operations	None	Most	Minimal
Preservation of Intercity Rail Corridor to the West	No	Yes	Partial

Note: While each system has alternatives, those for System III as described in Chapter 5 might result in significant changes in the above evaluation factors.

System II has been recommended because, as shown in the above tabulation, it would have superior performance characteristics (maximum savings in travel time, transfer flexibility, etc.) and its implementation would not depend on the availability of the railroad right of way. While System I appears to have a lower capital cost, the acquisition of the railroad right of way might reduce or eliminate this differential. In addition, System I would require termination of inter-city rail service to downtown Boston. System III would have decidedly inferior performance characteristics such as slower speeds, minimum travel time reduction, and limited transfer capability. In addition, System III would require elimination of the present "one seat" trip on the Beacon Street and Commonwealth Avenue Lines and imposition of a forced transfer in the Kenmore area. It should be noted that System III as evaluated herein is predicated on the use of low-platform vehicles in the early stages of improving the existing Central Subway in accordance with directions from the Authority and current development of the new No. 6 car. See Chapter 5 for an evaluation of the effect of using convertible cars capable of serving two different platform heights on the same line.

Western Corridor

Two potential systems in the Western Corridor were studied: System A would connect the proposed Framingham Extension to the Highland Branch at Riverside; System B would continue the Framingham Extension on the B & A Railroad tracks to Fenway Park. All of the system alternatives investigated would depend directly on the availability of varying portions of the Penn Central Railroad right of way. Therefore, the engineering and operational solutions proposed presume satisfactory negotiations with the agencies involved.

The Engineer Consultant was advised that the traffic forecasts furnished for System B were developed prior to the CASS study, and that they were based on different assumptions from those used for the System A forecast. Thus, direct system comparisons as developed for the basic CASS evaluation were not feasible in this study; accordingly, the comparisons described below include the various alternatives to the individual systems studied.

System A would cause minimum disruption of present Penn Central railroad operations but would require the largest capital expenditure. Two new tracks would be built from Framingham to Riverside on the now unused portion of the existing railroad embankment. The alignment would diverge from the existing railroad west of Route 128, with new structures over Route 128 and the Charles River, and connect with the Highland Branch at Riverside. Reconstruction of bridges, widening of embankment, and installation of retaining walls would also be necessary.

System A alternatives included one that assumed that railroad operations would be limited to a single track from Framingham to Riverside. In this event, two new bridges would be built, one over Route 128 and the other over the Charles River. All other bridge reconstruction as well as embankment and retaining wall work would be eliminated with significant savings.

A major fault of System B is that existing Penn Central Railroad operations (both freight and passenger) would have to be entirely discontinued between Riverside and Fenway Park. As noted previously, this does not appear realistic at the present time.

One alternative to System B postulated suspension of commuter railroad operations and limitation of Penn Central freight operations to a single track from Framingham to the Beacon Park Yards. Two-track transit operations would then be instituted from the Framingham area to Riverside as outlined for the System A alternative above. A single-track, high-speed rail rapid transit line could be extended from the vicinity of Riverside to Fenway Park and/or Back Bay, thus providing both express and local service to the downtown area for Western Corridor commuters.

Chapter 6 contains detailed descriptions of various Western Corridor alternatives.

The previous recommendation for the adoption of System A for planning purposes is reaffirmed on the basis of its implementability under existing circumstances. Recognizing that many factors which could have significant effect on detailed design may vary widely, however, it would appear prudent to anticipate some form of staged design and construction. An intermediate extension to the Wellesley Farms area would provide additional dispersed parking capacity west of Reservoir Station and effectively reserve the unused railroad right of way for future transit purposes. Evaluation of the initial extension and clarification of the future level of railroad activities in this corridor would result in a firm basis for selection of the appropriate alternative for ultimate construction.

Map of Boston - 1814

Chapter 2
THE PROJECT

BAY
TRANSPORTATION
AUTHORITY

Chapter 2

THE PROJECT

HISTORICAL DEVELOPMENT OF TRANSIT IN THE STUDY AREA

The Boston area has long benefited from pioneering efforts to instigate and improve urban transportation. Its transit system grew rapidly after the economy and reliability of the electric trolley car were demonstrated in Boston in the 1880's. The first subway in the nation was constructed and opened to traffic under Tremont Street on September 1, 1897. Bostonians accepted the new transit system eagerly; during the first year of subway operation, patronage reached 14,500,000 on the 30 surface lines operating in subway for a portion of their routes. From that time to the present, Boston's public transit system has included trolley cars routed via subways and suburban streets in combination.

Growth of the urban area and changing residential, employment and land use patterns required corresponding changes in the transportation system. The first multiple-unit trains for subway-elevated operation were inaugurated in the Tremont Street Subway in 1901. Other subways were built later to serve high-floor rapid transit cars. These new lines relieved operational difficulties experienced in the first subway. Rail transit remained a popular mode of travel in Boston, reaching a peak in patronage shortly after World War II. Although increasing automobile use has been accompanied by a steady decline in transit use since then, there is now renewed interest in rail rapid transit as a fast, comfortable, pollution-free and dependable system of urban transportation.

Changes in the Greater Boston Area have been particularly dramatic during recent years. An active program of urban renewal, significant commercial investment complexes such as the Prudential and Hancock developments in Back Bay, an improved highway network, and the unparalleled growth of the universities have all created new and challenging demands on the community's public transportation system. As the urban area changes, the transportation system serving it must be appraised and modified to assure its adequacy.

The Program for Mass Transportation, originally proposed by the Authority in 1966, was primarily directed toward extending service to the 79 cities and towns comprising the jurisdiction of the Authority. Subsequent revisions to the Program in 1968 and 1969 recognized the importance of continuing study directed toward solving the problems that such line extensions would create in the Central Area. Additional

Figure 2-1

EXISTING TRANSIT ROUTES

extensions to the Western and Northeast Corridors were suggested by the Eastern Massachusetts Regional Planning Project in its Recommended Highway and Transit Plan, January 1969. These recommendations gave priority to a detailed study of the transit capabilities and needs of the Central Area.

During the current study, previously proposed solutions to transit problems were reviewed and re-evaluated in the light of the present transportation situation. These earlier proposals were incorporated in this study where they were found to have remained valid.

THE CENTRAL AREA

Study criteria defined the Central Area as that area lying within the route of the proposed Inner Belt highway (Interstate 695). In addition to this primary study area, consideration was to be given to all surface streetcar lines, known as the Green Lines, extending westerly from the Central Area.

EXISTING TRANSIT LINES

The major public transportation arteries serving the Central area are four rail transit systems, called the Red, Orange, Blue and Green Lines in accordance with their identifying color schemes. Figures 2-1 and 2-2 show these four systems. Each transit line passes through the Central Business District in its own subway. Each line crosses two of the remaining lines, and there is a major interchange station at their intersection. Passengers can transfer at interchange stations, but there are no track connections between lines. At present it is not physically possible to run the equipment of one line on any of the others due to differences in clearances and platform heights.

The Green Line System

This system consists of four subway-surface lines equipped with low-platform trolley cars. This group, comprising the Riverside, Commonwealth Avenue, Beacon Street and Huntington Avenue Lines, is the oldest on the system, operating over routes that are severely restricted in many areas.

The Riverside Line, running between the Riverside and Lechmere Stations, is completely grade-separated. It runs on the surface in private right of way between Riverside and Fenway Park Stations, in subway to Haymarket Station, and on elevated structure to Lechmere Station. A turning loop, yard and shops adjoin Reservoir Station, approximately at the midpoint of the line. The major storage yard is at Riverside. There are inbound looping facilities at Kenmore Station, Park Street, Government Center and North Station.

LEGEND

MBTA BUS ROUTES
SUBURBAN BUS ROUTES

RAIL TRANSIT LINES

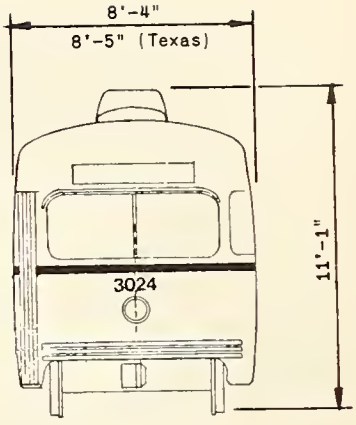
RED LINE
ORANGE LINE
ORANGE LINE UNDER CONSTRUCTION
GREEN LINE
BLUE LINE

Figure 2-2

EXISTING TRANSIT ROUTES IN CENTRAL AREA

The Commonwealth Avenue Line, also known as the Boston College Line, runs in the median reservation of Commonwealth Avenue between Boston College and the subway portal west of Kenmore Station. It operates in subway between Kenmore and Government Center Stations. Trains are turned back via the Government Center loop, or, in an emergency, via the Park Street loop. Crossovers are located at Brighton Avenue and at the portal. A 1,000-foot double-track connection is maintained to Cleveland Circle and Reservoir Station for non-revenue operation.

The Beacon Street Line, also known as the Cleveland Circle Line, operates in the median reservation of Beacon Street between Cleveland Circle and the subway portal near Park Drive. It runs in subway between Kenmore and Haymarket Stations, continuing on elevated structure to Lechmere Terminal Station. There is a crossover at Coolidge Corner, and inbound trains can loop at Kenmore Station, Park Street, Government Center and North Station.



GREEN LINE

Number of Cars: 343
Built: Pullman 1941-1951
Seats: 42 (Texas cars seat 49)
Maximum Capacity: 130
Length: 46'-0", 48'-0" (Texas)
Single cars, all multiple-unit except 25 Texas cars.
Crew Requirements:
One man per car

PCC Cars on Huntington Avenue at Northeastern University

The Huntington Avenue Line, also known as the Arborway Line, runs in South Street, Centre Street, South Huntington Avenue and Huntington Avenue to Brigham Circle. These route sections are not in median reservations. From Brigham Circle to Northeastern University, the line occupies the median reservation of Huntington Avenue, and continues in subway via the Copley Junction to a turnback loop at Park Street Station. Turnbacks can be made on the Heath Street loop and on crossovers at Brigham Circle and Northeastern University.

The Watertown Line was a part of the Green Line system until service was discontinued in June 1969. This was a street-running trolley car line from Watertown via city streets to the intersection of Commonwealth and Brighton Avenues; from this point, the line followed the route of the Commonwealth Avenue Line.

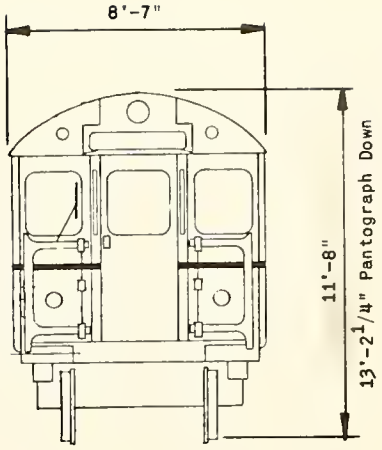
The other three transit lines in Boston use high-platform cars and are completely grade-separated. Traction power is carried either by third rail or by a combination of third rail and overhead wire.

The Blue Line

This Line is about six miles long. The line runs in subway from the loop at Bowdoin Station to Maverick Station; at that point, traction power pickup is changed from third rail to pantograph for the remaining surface portion to Wonderland Station.

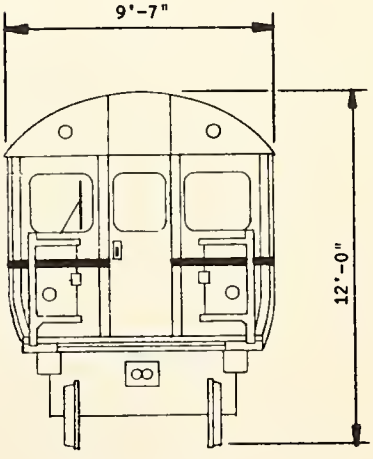
The Orange Line

This line runs 8.5 miles between Forest Hills to the south and Everett to the north. With the exception of about two miles of subway in the Central Area through the Washington Street tunnels, the line operates on elevated structure. It is powered throughout by third rail. The Haymarket-North Extension, now under construction, will relocate the line north of Boston and extend it to a new terminal in Melrose.



BLUE LINE

Number of Cars: 40
Built: St. Louis 1951
Seats: 48
Maximum Capacity: 177
Length: 48'-6"
Married Pairs, operated in 2- or 4-car trains
Crew Requirements:
2 in 2-car train
3 in 4-car train

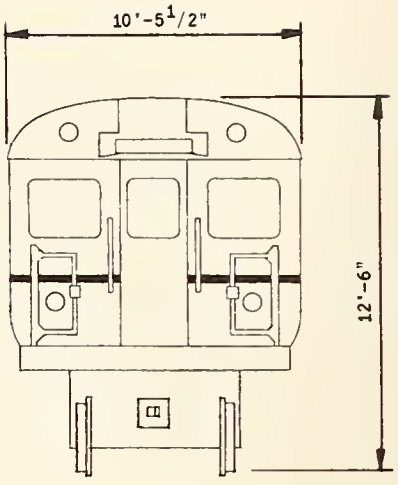


ORANGE LINE

Number of Cars: 100
Built: Pullman 1957-1958
Seats: 48
Maximum Capacity: 227
Length: 55'-0"
Married Pairs
Crew Requirements:
Same as on Blue Line trains.

The Red Line

This Line is also powered by third rail. It runs approximately nine miles between the Harvard and Ashmont Stations, with an additional 2.7 mile surface extension from Ashmont to the Mattapan Station. This latter portion, known as the Mattapan High Speed Line, is equipped with trolley cars. The high-platform rapid transit portion operates in subway between Harvard and Kendall Stations, between Charles and Andrew Stations, and between Fields Corner and Ashmont Stations.



RED LINE

Number of Cars: 92
Built: Pullman 1963
Seats: 54
Maximum Capacity: 308
Length: 69'-6"
Married Pairs
Crew Requirements:
Same as on Blue Line trains.

Additional data are given in the following table, comparing cars and trackage on the four transit lines:

COMPARISON OF KEY DIMENSIONS

Line	Top of Rail to Top of Platform	Minimum Track Radius	Centerline of Track to Edge of Platform	Track Gage
Green	2 1/2"	38'	-	4' 8-1/2"
Blue	3' 3"	75'	4' 6-1/8"	4' 8-1/2"
Orange	3' 6"	90'	4' 7"	4' 8-1/2"
Red	3' 11-1/2"	125'	5' 0"	4' 8-1/2"

EXISTING TRAFFIC

Traffic data gathered in the 1963 Home Interview Survey was used by the traffic consultant to the Authority to arrive at estimates of line volumes as shown on Figure 2-3. Traffic forecasts were updated as follows:

- A computerized traffic assignment network was developed using minimum time paths, with manual adjustments for intra-downtown trips, railroad-to-transit trips, and use of peripheral stations. Satisfactory agreement with 1964 station counts apparently was obtained.

- A downtown employment survey, made in 1969 and extended to 1975, was used to update 1963 data on distribution of trip ends.

- The transit system was modified to include improvements planned for completion by 1975.

- Estimated and projected population changes to 1975 were incorporated in the basic data.

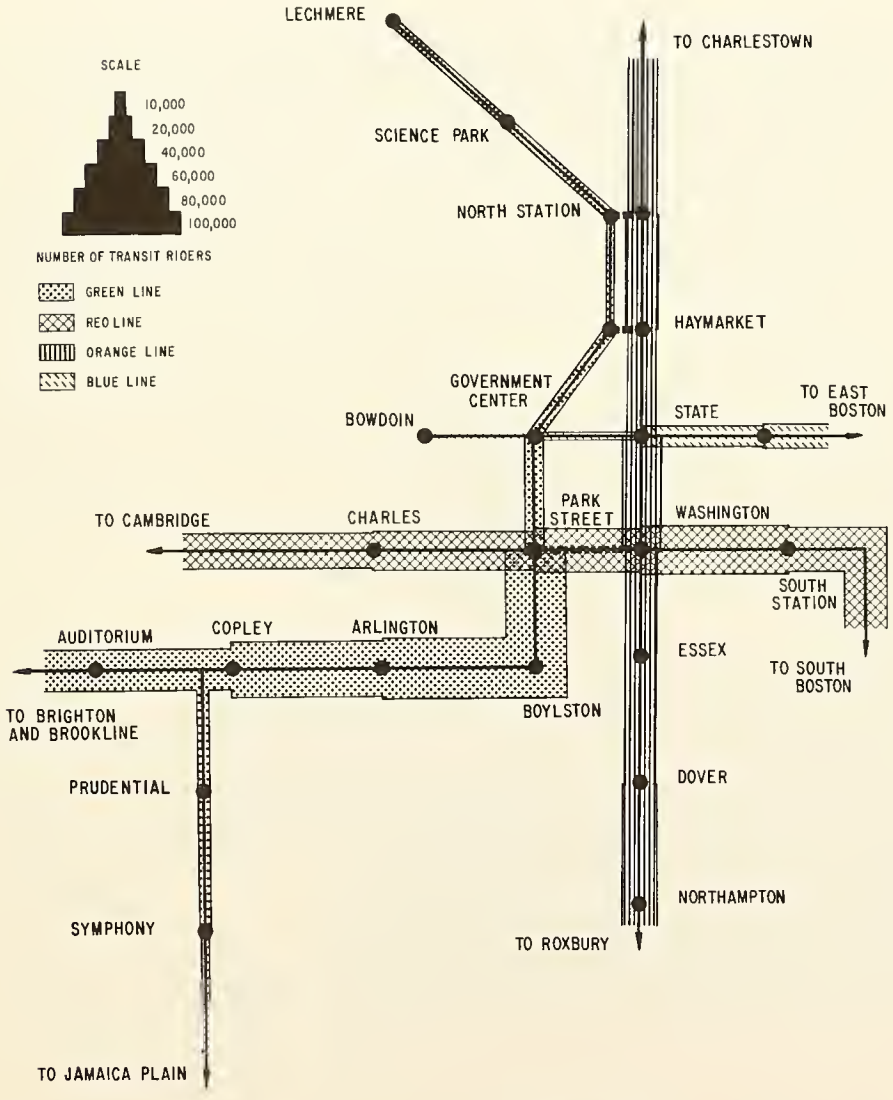


Figure 2-3

ONE-WAY DAILY TRANSIT RIDERS — 1963

OTHER MODES OF PUBLIC TRANSPORTATION

Rail

The Central Area is served by two commuter railroad companies--the Penn Central Company and the Boston and Maine Corporation. Both are subsidized by the Authority to ensure continuation of their commuter operations.

The MBTA Report on Alternative Programs for Suburban Commuter Service, dated January 1969, recommended that:

- "Commuter services continue on the Boston and Albany Line of the Penn Central as presently constituted;
- "Railroad services be operated as frequent-headway, high-quality diesel rapid transit lines to fully exploit the potential of this mode;
- "Where rail services are replaced by bus lines, these lines should feed rapid transit and rail stations, rather than operating into the Boston Business District."

The Authority is responsible for continuing service to communities now served by commuter railroads. If rapid transit could furnish service more economically than railroads--due to a more favorable ratio of revenue to operating costs--the Authority has indicated a willingness to undertake capital improvements for rapid transit extensions as a part of its long-range program.

Bus

Express bus service has been initiated over four routes on an experimental basis. These routes operate over Route 128 and the Massachusetts Turnpike between Riverside, Brighton Center, Watertown and the Central Area. Interviews with 94 percent of the 5,100 passengers making trips on a normal weekday indicated that approximately one-third were new patrons. That is, they formerly used automobiles or commuter trains, or had not previously commuted to the Boston Central Area.

Further experience with this mode of transit will better measure its value. The long-range capability of bus service will be limited, however, by the capacity of the major express roadways.

Highways

The proposed Inner Belt and Middle Belt are among expressways being planned for the Boston area. Public opposition toward addition-

al urban highways, however, has been evident in recent years. It appears increasingly necessary to convince residents that further improvement of the transit system must be accompanied by better highways if a viable and balanced transportation system is to permit revitalization of the densely populated urban areas.

The locations of proposed transit projects in the Western Corridor and their orientation to other modes of transportation are shown in Figure 2-4.

Figure 2-4

PROPOSED TRANSIT ROUTES IN THE WESTERN CORRIDOR

DEFICIENCIES IN THE EXISTING TRANSIT SYSTEM

Studies of deficiencies in the existing transit system were primarily concentrated on the serious operational problems afflicting the Green Lines. These problems exist in a variety of forms. Some are physical in nature, such as obsolete equipment and the poor riding qualities of worn track. Others are more intangible, such as the impact of transit deficiencies on the quality of life in suburban communities, and the possible resistance to change on the part of the residents of the area regardless of benefits. These problems result in an interrelated complex of conditions that deter efforts to expand the capacity and improve the quality of service on the Green Lines.

A brief survey of the more important engineering problems indicates the extent of such deficiencies in the existing system.

The Central Subway is structurally old and unsuited for high-speed operation. Clearances are substandard and sharp curves restrict speeds at several points.

The cars operating on the Green Lines are all of the PCC type, some of them nearly 30 years old. They have inherent limitations such as single-end operation, low-level platform loading, and insufficient door capacity. In addition, it has become increasingly difficult to keep these cars in operating condition. Breakdowns are frequent, repairs are costly, replacement parts are difficult to obtain, and maintenance facilities are poorly located, too small, and obsolete.

The number of Green Line trains being routed through the Central Subway creates congestion. During the morning peak hour, 74 trains are scheduled for passage over the single inbound track between Copley Junction and Boylston Station. The resultant theoretical headway of 49 seconds cannot be achieved. The practice of berthing more than one train at a station in an attempt to speed loading and unloading of passengers only adds to the confusion, as patrons move up and down the platforms. The scheduled running time is 34 minutes for the 7.4-mile round trip between Kenmore Station and Lechmere, but actual time is often 45 minutes during peak periods, and average speed drops to about ten miles per hour.

The opening of the Highland Branch in 1959 added about 15,400 inbound riders per day to the Central Subway. Although their fares were welcome, they added to congestion in the Central Subway. Moreover, due to inadequate funding when this route was converted from railway operation, the Highland Branch has contended with difficult conditions for more than ten years.

OBJECTIVES OF THE ENGINEERING STUDIES

The engineering studies reported in this volume were initiated to evaluate specific proposals for reducing congestion in the Central Subway and for connecting the Riverside Line with the Blue Line. A third initial objective was to develop a program of improvements for the Green Lines system, including trackwork, traction power, signals, station modernization, and vehicle maintenance.

The original study was later expanded to include possible transit extensions in the Western Corridor. Such extensions would affect the Green Lines and the possible interconnection of the Riverside Line with the Blue Line. Western Corridor studies were conducted concurrently with Central Subway studies, therefore, and combined for presentation in Volumes II and III of this report.

Throughout the study, valuable assistance was obtained from the Metropolitan Area Planning Council, the Eastern Massachusetts Regional Planning Project and the Boston Redevelopment Authority. Meetings with officials and planners of the cities and towns in the study area were helpful in evaluating alternatives for improvements.

Overall objectives of the combined studies were to recommend immediate-action and long-range improvement programs that would increase the capacity and quality of service in the Central Area and Western Corridor, consistent with the objectives of the Authority's "Program for Mass Transportation".

SCOPE AND DEVELOPMENT OF STUDY

Organization of the Central Area Systems Study was defined in the CASS Application for a Technical Studies Grant, dated May 27, 1968.

General supervision of the study was furnished by the Project Manager of the Massachusetts Bay Transportation Company. He was assisted by MBTA staff specialists in the Department of Engineering and in the Planning and Development Office.

Three consultants contributed to the Federally-aided portion of this study. De Leuw, Cather & Company conducted engineering feasibility studies, formulated the systems, and estimated the cost of proposed projects; Peat, Marwick, Mitchell & Co. (formerly Peat, Marwick, Livingston & Co.) were responsible for traffic projections; and the Metropolitan Area Planning Council conducted the social and economic study.

Upon receiving notice to proceed on October 9, 1968, the data collection process was begun and CASS technical studies were initiated on

the major work items outlined in the Application for a Technical Studies Grant, dated May 27, 1968.

A PERT chart was prepared to outline the time-oriented interrelationship of tasks by the various organizations charged with performance of the study.

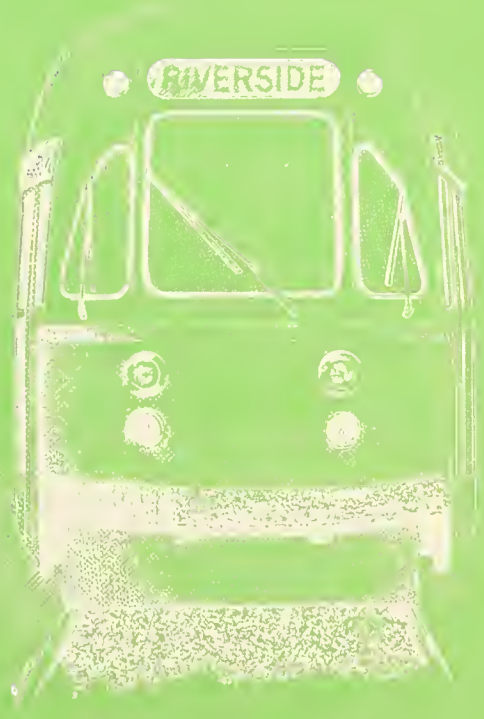
Application for a Supplemental Technical Studies grant was made on December 23, 1968, to finance the study of possible line extensions in the Western Corridor. The results of these studies are reported in Chapter 6. As indicated previously, the strong relationship of the Western Corridor study to CASS made it highly desirable to work concurrently on the two assignments.

As the studies advanced, the Authority requested performance of several design tasks that were related to the project. A study of clearance diagrams was made to determine the optimum transit car that could be operated in existing subways. A speed-time study of the Highland Branch compared existing running times with those which would be obtained by operating new cars over upgraded track. The Orange Line connection study investigated joining the Green and Orange Lines near Back Bay Station. This study is described in Chapter 5.

Previous studies and reports were reviewed to determine to what extent they were still relevant. Even though conditions had changed since some of these studies were made, they were found to contain valuable background information. These documents are listed in the bibliography at the close of this volume.

The concept that alternative systems of improvements should be developed--as opposed to individual design alternatives relating to specific problems--evolved in the early phases of the study. The systems concept reflected the interrelationship of study factors; for example, an alternative such as the reuse of the presently abandoned Tremont Street subway, even though this were to prove feasible, would be valuable only if it could be fitted into a system that utilized this facility as a portion of the route.

As better information regarding traffic volumes, community planning objectives and urban renewal projects became available, three systems emerged as possible answers to the problems of the Green Lines, subject to the assumptions inherent in their formulation. The first-stage improvements described in the following chapter are those most urgently needed and, therefore, the ones most likely to be implemented. Later stages described in Chapter 4 are more likely to require modification as better information becomes available and as underlying assumptions are subjected to testing. However, the systems concept forms the framework for the entire program of improvements including those recommended for the first stage.



New No. 6 Car

Chapter 3

IMMEDIATE ACTION PROGRAM

MASSACHUSETTS BAY TRANSPORTATION AUTHORITY

Chapter 3

IMMEDIATE ACTION PROGRAM

Urgent problems apparent in Green Line transit system operations led to development of a program for immediate action. This program includes recommended improvements in trackwork, stations, traction power, signals, communications, rolling stock, vehicle maintenance, and operations.

The Immediate Action Program would be compatible with any one of the three systems of long-range improvements described in Chapter 4, and would constitute Stage 1 of each alternative system.

The importance of this Program was indicated by its inclusion in the Authority's Request for Increased Bonding Authorization submitted to the Joint Committee on Transportation in January 1970.

OBJECTIVES

The improvements recommended for immediate implementation were developed to achieve the following objectives:

- To reduce travel time between stations on the Green Lines;
- To increase the dependability of transit service on the Green Lines;
- To reduce maintenance and operating expenses;
- To improve passenger comfort and convenience.

Modernization of plant, replacement of worn equipment, and utilization of current transit operations technology are urgently needed to increase the operational efficiency of the Green Lines and hence community acceptance of the transit system.

RECOMMENDED ROUTE OPERATIONS

On-street portions of the Green Lines not in medians should be eliminated to improve the operations of these lines.

Trolley cars were replaced with buses on the Watertown Line between Watertown Square and Packards Corner in June 1969. Elimination of operation of trolley lines in mixed traffic is a policy that should be pursued further.

PCC cars and motor vehicles compete in city streets on the Arborway Line between Arborway and Brigham Circle. This section would be served better by buses. Patrons of the remaining portion of the Arborway Line, hereafter referred to as the Huntington Avenue Line, would benefit through shorter running time and more frequent service.

The Riverside Line should continue to operate over its route between Riverside and Lechmere via the Highland Branch, Central Subway and East Cambridge viaduct. The Commonwealth Avenue Line and the Beacon Street Line should also continue without routing changes. The Green Lines System is shown in Figure 3-1.

ROLLING STOCK

Phase I of CASS and subsequent discussions with the Engineering and Operations Department of the Authority revealed the increasing frequency of PCC car breakdowns. This poor performance is largely attributable to the age of the cars used on the Green Lines:

- Most of the cars are nearly 30 years old.
- Replacement parts are difficult to obtain and often must be made to order.
- The many different models of PCC cars in use make it difficult to standardize maintenance procedures.
- The cost of maintaining PCC cars is high as a result of the above factors.
- Speed-limiting devices have been installed on PCC cars to reduce the incidence rate of failures.

Previous reports have recommended that PCC cars be modified to provide:

- Double-ended operation.
- Additional left-hand doors.
- New resilient wheels.
- Restoration of original balancing speed of 42 miles per hour.

Due to the deteriorated condition of the PCC cars, however, it is recommended that they be phased out instead and replaced with new rolling stock.

Figure 3-1

THE GREEN LINES SYSTEM
IN STAGE I

Early in 1969, the Authority decided to design 130 new low-platform subway-surface cars, designated as No. 6 cars, for initial operation on the Riverside and Huntington Avenue Lines. In later stages these cars would be transferred to the Beacon Street and Commonwealth Avenue Lines.

Instead of 130, more than 200 such cars would be required to replace the entire fleet of PCC cars now operating on the Green Lines. Therefore, those PCC cars most suitable for intermingled operation with the new No. 6 cars in the Central Subway would be equipped with a new signal system described later in Chapter 3.

If the Authority decided to replace the entire fleet of PCC cars, installation of new signal equipment on any of the PCC cars on the Green Lines would be unnecessary. In this event, it is recommended that all No. 6 cars be equipped with overhead pantograph power pick-up. The power distribution and supply systems on the Beacon Street, Commonwealth Avenue and Lechmere Lines, furthermore, would be converted to make them compatible with the new catenary power distribution system that would be built on the Riverside and Huntington Avenue Lines in this stage.

See Volume I of this report for specifications and estimated cost of the new No. 6 cars.

Proposed No. 6 car

Operator's control area inside proposed No. 6 car.

TRACK AND ROADBED ON THE RIVERSIDE LINE

The Highland Branch of the Boston & Albany Railroad became the Riverside Line of the Metropolitan Transit Authority on July 4, 1959. Bad ties and rails with excessive wear were replaced, and track on the entire line was surfaced prior to opening day. The riding quality of the line remained poor, however. The bolted joints opened in winter, resulting in a noisy ride. Slow railroad traffic, using cars with large diameter wheels, had tolerated this condition; the lighter PCC cars, operating at higher speeds with smaller wheels, required better track for acceptable levels of comfort for passengers.

Starting in 1960 and continuing for several years, bolted joints were replaced with thermite welds, producing continuous welded rail and a smoother ride. Expansion of track during hot summer days, however, caused serious alignment problems when the track shifted on the gravel and cinder ballast. Thirteen hundred tons of crushed stone were added to the track and shoulders during 1965 and 1966 in the expectation that the keying action of angular stone ballast would deter lateral shifting. Track maintenance problems, however, have continued to plague the operation of this line.

Inspection and evaluation of track condition on the Highland Branch resulted in the following recommendations:

- Approximately 40 percent of the track should be replaced immediately for safer and more efficient operation. The type and quality of materials should be those generally used in rapid transit operations. The ultimate objective should be replacement of all track on this line.

- Track replacement should be carried out in long sections at a time, rather than in short sections or spot renewals of selected track materials. A long-section program would permit simpler work staging and cause less disruption to train service than the alternative plan.

The track between Fenway Park Station and the Riverside Terminal was inspected in April 1969. Rail wear was measured and the general condition of the track was noted on this 9.3-mile section of double track.

A tabulation of specific observations made on this inspection is given in the following table:

CONDITION OF TRACK--RIVERSIDE LINE

	Section of Track					
	Fenway to Brookline Village	Brookline Village to Reservoir	Reservoir to Newton Center	Newton Center to Waban	Waban to Riverside	Remarks
Distance, Feet	5,950	9,100	13,180	12,790	7,930	
Rail* Condition, topwear:						Excessive top wear at station approaches.
Inches and ()% of 85-lb. rail	3/8" (15%)	1/8" (67%)	1/4" (90%)	1/8"	Minimal	
Inches and ()% of 100-lb. rail		Minimal			1/4" (39%)	
Inches and ()% of 105-lb. rail	3/8" (10%)	3/8" (22)	3/8" (38%) 1/2" (15%)	3/8" (50%) 1/2" (18%)	3/8" (28%) 1/2" (28) 1/4" (39%)	
Rail Condition, side wear--Inches			1/4" to 3/8"	1/8" to 1/4"	1/4" to 3/8"	
Track Alignment		Poor on transitions				
Track Surface	Poor	Poor	Poor	Poor		Wood shims used.
Condition of Welded Rail Joints	Sagging	Sagging		Sagging		
Condition of Timber Ties	Rotting, split, plate-worn	Replace 55%	Replace 55% (1926-31)	Replace 50%	Replace 30%	
Condition of Tie Plates	Loose	Loose	Loose	75% loose		Spikes have excessive clearance.
Rail Anchors	Not enough			Not enough	Not enough	Rail creep noticeable.
Condition of Ballast	Dirty	Dirty	Dirty	Dirty	Dirty	Original cinders covered with stone.
Width of Ballast Shoulders	25% deficient	Deficient	50% deficient	Deficient	65% deficient	
Drainage Conditions	Poor	Poor	Poor	Poor	Poor	

*-Existing rail is of the following types:
85-lb. ASCE tee, 1945, 1958-1964, 1968
100-lb. RA-B, 1964-1967
105-lb. 6" Dudley tee, 33' lengths, 1913 and 1925

All rail is continuously welded with thermite welds.

Several conditions deserve special attention:

- Extremely poor track drainage conditions exist on the outbound track at the coal and oil yard between Longwood and Brookline Village Stations.

- The special trackwork in Reservoir Yard is good; however, general cleanup, added ballast and retamping would extend the useful life of this yard.

- Running water is undermining the shoulders and subgrade of the outbound track west of Reservoir Road.

- Plugged outlet drains cause standing water in ditches along the outbound track west of Herrick Road at Newton Center Station.

- Poor drainage conditions exist on both sides of the track east and west of the Rogers Street bridge, and also west of the Boylston Street bridge near Cooks Junction.

- Poor drainage conditions need attention west of the Beacon Street bridge, east of Woodland Station, and west of the Washington Street bridge near the golf course grade crossing.

- Riverside Yard is generally in good condition. The 85-pound rail in the outer loop shows three-eighths inch wear. Special trackwork components appear to be well-maintained.

Track Improvements

Existing track conditions restrict the quality and speed of operations on the Riverside Line. An intensive maintenance and renewal program should be started with a goal of ultimate replacement of all track elements on this line.

Based on recent observations and measurements of the top and side wear of the rails, and assuming one-half inch as the maximum allowable wear, about four percent of the existing 85-pound rail and 53 percent of the 105-pound rail should be replaced with new welded 115-pound rail. This would result in replacement of approximately 36 percent of the total length of rail now on the line.

In addition, about 56 percent of ties and tie plates should be replaced. Two-block concrete ties--such as the SRS Type 101 or the RS Type SL--are preferable to timber since they are more economical, have longer life, require less maintenance and produce a heavier and more stable track. Ties should be spaced at 30 inches, with insulated fastenings such as those currently being installed on the South Shore extension. Proposed details for track on ballast are shown on Figure 3-2.

Where track would not be replaced in Stage 1, additional rail anchors should be used to prevent movement of the rails. A minimum of ten compression rail anchors per 39-foot section--eight forward and two reverse--should be used. In areas where a serious expansion problem exists, this number should be increased to 12 anchors per 39-foot section--eight forward and four reverse.

A program of through re-ballasting, surfacing and aligning should be carried out in connection with the improvements already mentioned. Tracks should be raised at least four inches in Stage 1, using good quality one and one-fourth inch crushed stone ballast. Particular attention should be paid to the strengthening of ballast shoulders. Overhead restrictions such as contact wire and bridge clearances would be factors in setting a profile for re-ballasting operations.

Portions of track scheduled for replacement in Stage 1 include:

- Curved portions of track where spirals would be lengthened and superelevation increased.
- Main line inbound track through Reservoir Station which would be realigned to parallel the outbound track.

Other trackwork to be performed in this stage consists of:

- Rehabilitation of existing turnouts and crossovers.
- Installation of new emergency crossovers near stations.
- Construction of new track connections and storage tracks at Reservoir Yard.
- Rehabilitation of the existing Riverside Yard.

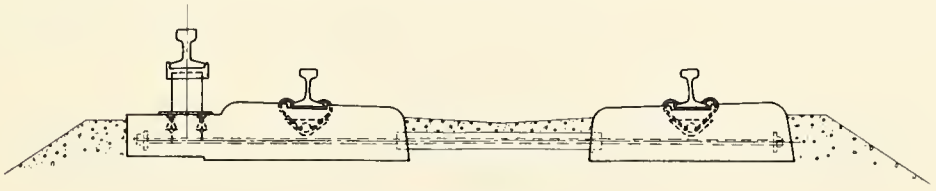


Figure 3-2
PROPOSED TRACK ON BALLAST

The estimated costs of the above work items on the Highland Branch are as follows:

Main Line Tracks and Roadbed	$2,273,000
Special Trackwork	315,000
Riverside and Reservoir Yards	735,000
Drainage	87,000
Total	$3,410,000

In addition, worn rail in the Central Subway and on the East Cambridge Viaduct would be replaced with new 115-pound welded rail. The remaining rail joints would be welded and the track surfaced and aligned. Ballast would be added where required, and hardware and new ties would be installed. Reverse curves would be modified where feasible to improve alignment.

The cost of improving the track and roadbed in the Central Subway and on the East Cambridge Viaduct is estimated at $1,014,000, bringing the total estimated cost of track and roadbed improvements in Stage 1 to $4,424,000.

TRACTION POWER

To furnish the additional power and voltage regulation required for the new No. 6 cars, and to correct the present low voltage condition at the Riverside Terminal and Yard, new substations would be built at Riverside, Hammond Pond and Reservoir. The remaining existing substations currently feeding the Green Line System--Cooks Junction, Coolidge, Oak Square, Newbury, Central, Dewey and North Station--would have sufficient capacity to meet the Stage 1 peak hour demands of the remaining portions of the systems not covered by the new substations. Locations and capacities of the new substations provided in this stage would be based on the future power system requirements for high-level rapid transit operation on the Riverside Line.

With the addition of the new substations, the capacity of the present direct suspension overhead contact wire and supplemental feeder system between Riverside and Fenway Park would be adequate for the trolley pole operation of the new No. 6 cars, but would not permit full exploitation of their higher speed capabilities.

It would be necessary, therefore, to convert the present overhead to a catenary system to permit higher speed operation with such cars over the Riverside and Huntington Avenue Lines in Stages 1 and 2. In later stages, the Beacon Street and Commonwealth Avenue Line trains would also operate over the Highland Branch to the proposed Riverside shops for maintenance of No. 6 cars transferred to these lines.

The catenary system would also be suitable for pantograph collection and thus could be retained as the permanent overhead for the ultimate high-platform rapid transit operation outside the limits of subways.

The existing No. 2/0 contact wire system in existing subways would be removed and replaced with subway-type catenary construction wherever clearances would permit. In areas where vertical clearance would not permit catenary construction, the existing No. 2/0 contact

wires would be removed and replaced with No. 4/0 wires; present supports from tunnel roof would be replaced or adjusted to provide as smooth an operation as possible. Capacity of the present supplemental feeder system within the limits of the subway would be adequate for the proposed combined operation of the new No. 6 cars and of existing PCC cars during this stage.

Since the direct suspension overhead contact wire and supplemental feeder system between the existing portal at Haymarket Station and Lechmere would be removed in Stage 3, and since the existing system would be adequate for the combined operations of the new No. 6 and existing PCC cars on the Riverside and Beacon Street Lines during stages 1 and 2, it is recommended that this portion of the system be retained during earlier periods. Existing contact wires should be retensioned and realigned, however, to provide as smooth an operation as possible.

The cost of a new catenary system from Riverside to the Haymarket portal, improvements to the existing overhead from the portal to Haymarket to Lechmere, and three new substations has been estimated at $4,367,000.

SIGNALS AND COMMUNICATIONS

Present System

The Highland Branch and Central Subway operate under common interlocking and automatic block system rules. The Central Subway also operates under rules governing entrance to stations.

Speed is regulated at several locations through wayside signals setting minimum approach times; these signals, designed to restrict speed to safe levels, are used to limit speed on curves.

Mechanical train stops on other MBTA lines enforce obedience to a "stop" signal but have no speed control capabilities. When a train passes a "stop" signal, the mechanical train stop engages a trip cock on a car-carried air brake system releasing compressed air and applying the brakes. The effectiveness of mechanical train stops is questionable when trains travel at high speeds. Since track trips are exposed to weather, they are subject to freezing and blockage by snow or sleet. False tripping is also a common occurrence. Electric snow melters do not completely assure satisfactory winter operation. For better protection, the effective point of stoppage should be full braking distance behind a preceding train. Generally this results in double "red" block signalling where two "stop" signals separate trains.

Interlockings are automatic in that route selection for diverging movements is established by trolley contactor.

The present signal system has no positive facilities to enforce the operator's obedience to signal rules. Such rules were established in the Authority's "Rules for Operators and Other Employees of the Surface Lines", dated May 1, 1969.

These rules do not specify where, on which track, nor in what direction the authorized aspects and indications apply. It is assumed, therefore, that this information is included in qualifying procedures for Operators.

These rules may have been based on occurrences in years past that led to accidents. With such restrictions, however, little improvement in interlocking operations can be expected. We recommend that regulations be modernized to make expeditious use of the switches and interlockings. Adequate control and safety measures must be retained, of course. Mechanical train stops are not recommended for the Green Line.

Recommended Signal System

Alternative signal systems were evaluated on the basis of protection afforded and costs. Wayside signals with train stops were compared with a cab signal system with overspeed controls for possible use in the intermingled operation of two types of rolling stock: the new No. 6 car and existing PCC cars.

It is recommended that a signal system be installed which would provide automatic train protection by imposing penalizing brake applications when an operator failed to respond to a signal command. A multi-speed cab signal system with overspeed controls is proposed. This system would be designed to:

- Prevent rear end collisions resulting from one train overtaking another;
- Prevent conflicting routing of trains and eliminate the present "one minute wait" rule;
- Provide Automatic Car Identification (ACI) and Automatic Train Dispatching (ATD);
- Eliminate hazards resulting from operator failure to see wayside signals and from vandalism of signals;

- Prevent derailments caused by train speeds exceeding the design speed of the track;

- Eliminate the need for timing sections;

- Permit a train to "close in" on a station platform or to assist a train ahead.

Modular and plug-coupled equipment could easily be installed on existing PCC cars, and a major portion of the equipment could be reused on the new rolling stock. The system could be expanded to other routes in the ultimate stages.

A multi-speed signal system would improve operations in several additional ways. With conditions ahead continuously displayed, the operator would be able to take advantage of favorable track conditions without waiting until the next wayside signal came into view. In addition, close headways would be possible at higher operating speeds despite the intermingling of cars with different operating characteristics, since the speed of each car would be individually controlled by the signal system.

The recommended multi-speed system would provide over-speed controls permitting:

- A maximum operating speed of 55 to 60 miles per hour on the Highland Branch for the proposed No. 6 cars;

- A maximum speed of 40 miles per hour in the Central Subway, the Lechmere Line and on surface trackage for the No. 6 cars and PCC cars;

- A normal medium speed of 25 miles per hour in the Central Subway and on the Lechmere Line;

- A maximum speed of ten miles per hour for closing in at station approaches;

- A maximum "Stop and Proceed" speed of ten miles per hour. This would allow a train to enter an occupied block or proceed through a defective block, and would also be the no-code speed for the system.

These speed control criteria are illustrated in Figure 3-3.

The cost of the recommended signal system has been estimated at $9,601,000, complete except for the car-borne equipment. The total system includes the following components:

Track Circuits and Wayside Equipment	$5,025,000
Interlockings	3,584,000
Automatic Car Identification (ACI)	807,000
Automatic Train Dispatching (ATD)	185,000
Total	$9,601,000

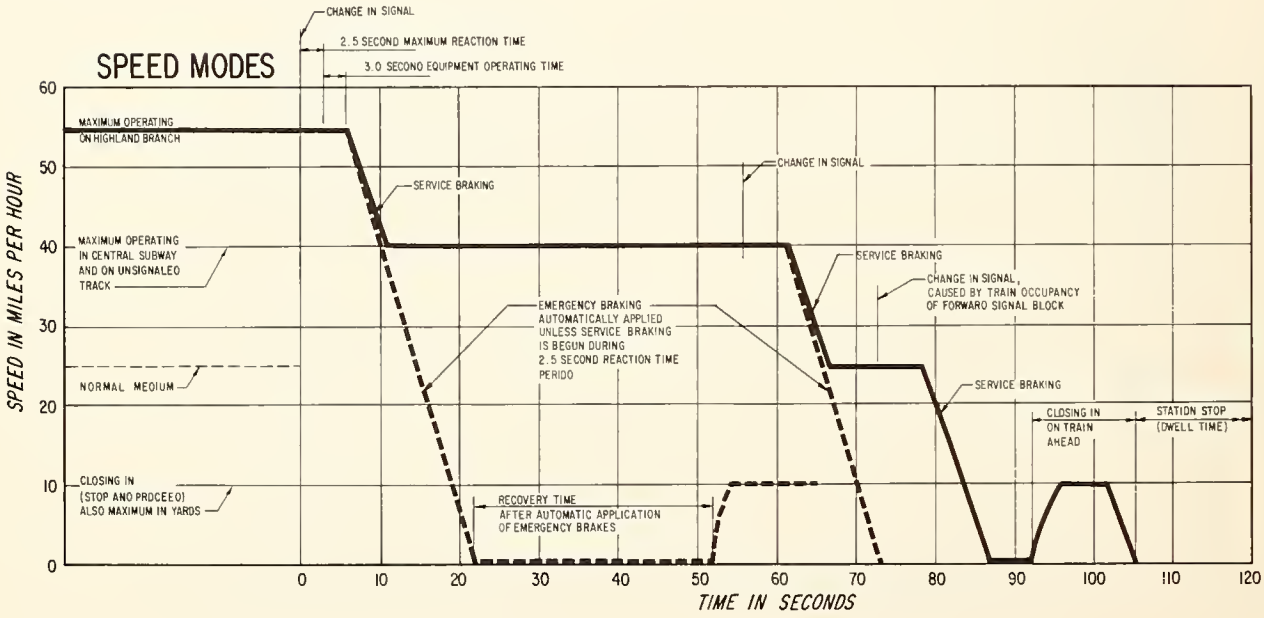


Figure 3-3
SPEED CONTROL CRITERIA

Car-Borne Equipment

Signal equipment required on each PCC car would consist of two receiving coils mounted on the front truck, a speed detecting device, a set of electronic and relay logic equipment that could be mounted under a seat in the car, a cab signal indicator combined with a speedometer located at the operator's position, and an interconnection between the signal system and the car brake system.

The receiving coils would be inductively coupled to the track, receiving carrier energy from the rails. This coded carrier energy would be filtered, amplified, and decoded electronically to produce outputs which activate the speed commands. The energy required to operate the signal system would be derived from the car battery at an estimated 28 volts. The connected load to the battery would not be expected to exceed two amperes.

The estimated cost of equipping the two types of PCC cars with cab signal equipment is $8,000 per car. See Appendix F for cost data.

When the existing PCC cars were retired, the cab signal equipment could be removed and reused on new cars. The estimated value of this equipment is $5,000. The salvageable items would include the aspect display unit, the pickup coils, the speed sensor, and the relay logic equipment. The only items that could not be salvaged would be the interconnecting wire and the pickup coil brackets.

A cost advantage of the system would result from operation of two-car bi-directional train units with a single operator's control area. It would be necessary to equip only the controlling car. In the event that the Authority acquired only "B" type (double-ended single) cars, all cars should have the proposed multi-speed signal system equipment.

The operation of the cab signal system in signaled, unsignaled and yard areas would be as follows:

- In signaled territory--such as the Central Subway, the Highland Branch and the Lechmere Line--the cab signal system would replace the existing wayside signal system; train speed would continue to be restricted by existing signals, however, where required by block occupancy or physical limitations such as curves or grades.

- In non-signaled areas--such as on Beacon Street, Commonwealth Avenue, and Huntington Avenue--new cars would be restricted to a maximum speed of approximately 40 miles per hour, consistent with existing PCC cars.

- In yard areas cars would operate at the Stop and Proceed speed of ten miles per hour. A cut-in loop or track circuit would be required at the yard entrance on the non-signaled lines and at the limit of cab signal territory on the signaled line. Since standard yard speed is now ten miles per hour or less, track circuit equipment in the yard itself would not be necessary.

It is impossible to guarantee that cab signal equipment will cut in when a train enters cab signal territory. The fail-safe electronic components used in this system, irrespective of their high quality, are still subject to failure.

To minimize the possibility of a defective train leaving the yard, and to alert motormen that cab signal equipment is inoperative, the following is recommended:

- A test loop or track circuit should be installed between the yards and the main line. This circuit would permit operation of wayside equipment so that a complete cycle of speed commands would be transmitted to the train. The motorman would monitor cab signal equipment response.

- Two wayside signals should be installed at approaches to the Central Subway from unsignaled territory. The first signal would indicate block occupancy. The second would be time-controlled to assure that the train remained in the track circuit long enough to obtain a complete set of speed commands.

A track circuit should be installed at the limit of cab signal territory. This circuit would cut out the cab signal system and limit the maximum train speed to 40 miles per hour. A sealed push button would be provided to accomplish the cut-out in the event that the cab signal system did not cut out automatically. This would be necessary since continuing operation of the cab signal system would limit the train to ten miles per hour in the no-code area.

A theoretical headway of 60 seconds would be possible in the Central Subway and at junctions, since the train clearance time plus the equipment operating time would approximately equal the station dwell time. For sample block layout see Appendix F.

Interlockings

Train operation through interlocked track junctions is governed by MBTA operating rules which specify maximum operating speeds of six miles per hour together with additional precautionary procedures on approach to and travel through interlockings. It was observed that operators frequently brought trains to a full stop before entering an interlocked route; at certain Central Subway stations, trains were brought to a second stop.

Operational restraints may be partially due to the possibility of splitting switches. Failure of a wheel or pair of wheels to follow the proper rail results from track or track structure unsuited to transit-

type trucks. Such hazards would be minimized by making the track improvements recommended and by maintaining track and equipment properly.

The low operational speeds permitted are not a function of track alignment or switch curvature, however, but are dictated by present route selection facilities. At present, routes are established at interlockings by the manual manipulation of trolley contactors (overhead pans) by the operator. Installation of speed control-cab indicator and train identification systems would permit a substantial increase in operating speeds through track junctions, and hence improved headways and scheduling.

Interlockings should be fully protected with safety devices. It was observed that a number of power-operated switches had dual controls, and that the manual controls were not protected against unauthorized or unsafe operation. All dual-controlled switch gear should be provided with locks.

Single-level crossing interlockings--such as the Copley Junction and the Beacon Street Junction--have constituted major constrictions of Central Subway operations.

Optimum relief of congestion, especially at the Copley Junction, could be achieved by grade-separating the conflicting movements. Grade separation would require large capital expenditures, however, and could hardly be justified in light of possible future route changes. The least expensive Copley Junction operating improvement is deemed to be the one described in Appendix F.

The Copley Junction problems were also studied by J. I. Williams of the MBTA Planning Department. In his report on "Proposals to Expedite the Flow of Train Traffic Through Copley Junction", Mr. Williams recommended installation of an automatic train dispatcher capable of adjustment for peak and off-peak operation.

The route through the junction would be pre-established during the Copley Station stop for the outward non-diverging traffic. The route for traffic diverging to Huntington Avenue would be established enroute to Copley Junction.

Although congestion is not as serious at the Beacon Street Junction, it would be practical to establish a simplified right of way procedure for this junction, eliminating the stopping of unopposed trains.

Despite the reliability of recommended systems, no automatic equipment can be pre-programmed to meet all contingencies. Local

control facilities would be required at all important locations. It is recommended that when the proposed central monitoring facility becomes available, routing of trains through interlockings be controlled from this center.

The cost of interlockings to be installed in this stage is estimated at $3,584,000.

Automatic Train Dispatching (ATD)

Automatic train dispatching equipment indicates departure times for specific trains by means of a display. It is also used on turnbacks and interlockings, together with train identification, to ensure proper sequence of trains by destination.

The essential purposes of such equipment are to alert operators and control offices that a departure has been missed or delayed, and to prevent trains from capturing or holding route junctions on one route to the detriment of trains on converging routes.

It is recommended that automatic train dispatchers be installed at each main terminal; at Park Street Station for the sequencing of trains enroute to Huntington and Commonwealth Avenues; at Government Center Station for proper insertion of Boston College trains between Riverside and Beacon Street trains; and at the Copley and Beacon Street Junctions to improve train movements. The total estimated cost of these installations is $185,000.

Automatic Car Identification (ACI)

Automatic car identification systems (ACI) permit continuous tracking of individual cars from a central control. Cars are identified by number and by destination. It is recommended that ACI equipment be installed in each new No. 6 car and in all PCC cars to be retained. Cars would be identified by permanently affixed labels corresponding to car number. In addition, each car would be equipped with changeable destination labels interfaced with the visual car destination signs. Label location would have to be uniform on all cars.

ACI equipment would be used to route trains through interlockings. A specific route would be established while a train was leaving a station or approaching an interlocking signal. Interlockings would be programmed to favor a specific route during peak hours and then revert during off-peak hours to first come-first served scheduling.

ACI would afford the opportunity to use interlockings to their capacity. Speed through the interlocking would be limited only by track alignment.

The automatic car identification system would also record mileage and hours of service for each car. The information derived would be used in computing operating costs.

While ACI would be valuable in pre-selection of interlocking routes and traffic control, the system would not be a cure-all. Because of the complexity of train operations in the Central Subway system, a detailed operational analysis is recommended before selection of locations for wayside components of train identification equipment. At certain stations wayside equipment will probably be required in the platform areas themselves. The cost of Automatic Car Identification (ACI) has been estimated at $807,000.

Installation of ACI equipment would permit station signs announcing the destination of arriving trains. Such signs are recommended for a number of Central Subway stations including Kenmore, Auditorium, Arlington, Boylston, Copley, Park Street, Government Center, and Haymarket. At Arlington Station, where platforms are relatively narrow and the view of approaching trains is obstructed by columns, signs would be particularly helpful to passengers; they would permit the operation of four-car trains through this station as well as reducing station dwell time. The estimated cost of automatic destination signs is $350,000, and is included in the Communications estimates.

Communications

A two-way voice communication system between moving vehicles and dispatchers is recommended. Such a system would permit operators to receive and respond to dispatchers' inquiries without broadcasting to all vehicles. Emergency broadcasting facilities should also be provided.

To preclude the possibility of interference with communication systems for other routes, it is recommended that a separate frequency be established for the Green Line system.

Remotely-controlled transmitters and receivers would be installed. Since center walls and columns would attenuate radio signals, special antennas and transmitters would be required in the Central Subway.

Public address systems are recommended for the new No. 6 cars and those PCC cars to be retained. PA systems would permit announcement of station stops, connecting points, fare limits and so forth. The PA system should be integrated with radio equipment and interconnections furnished between operators, conductors and guards. Concealed controls should be furnished to permit police patrol alarm; activation would produce a specific signal on the radio system, the intercommunications system, or both systems.

Operator communication equipment would include a hand telephone, held in place by spring retainers on the control console and equipped with a finger-operated "press and talk" bar switch. A three-way switch would allow the operator to select radio or public address systems; the transmitter would serve both the radio communication and public address systems; the receiver would be common to radio and intercommunication systems. The cost of car-borne radio equipment has been estimated at $3,180 per car, assuming operational capability at both ends of the car.

Radio communication would largely eliminate the need for wayside telephones for emergency use. Portable radio sets for wayside personnel--particularly maintenance forces, highway vehicles assigned to maintenance, and supervisory personnel--would provide almost constant communications capabilities. The estimated cost of $2,651,000 includes automatic destination signs and all radio communications installations exclusive of car-borne equipment.

Day-to-day operating and supervisory communications rarely need to be broadcasted; as soon as the Central Control is available for Central Subway tie-in, therefore, the communications system should be expanded to include wayside communications serving stations, substations and trackside supervisory locations. All emergency control panels, interlockings, and main towers should be equipped with telephones. Equipment installed in Stage 1 would have components that would facilitate future connection to Central Control.

Wired monitoring systems are recommended for fire and smoke surveillance, water-level surveillance in pump rooms; power supply surveillance; and other critical conditions.

Station surveillance via closed-circuit television would permit monitoring of traffic flow, and detection of criminal acts and vandalism. Prominently displayed TV cameras, high intensity lights and public notices that stations were under television surveillance would in themselves constitute deterrents to violence and vandalism. Provision for installation of closed-circuit television has been made in all fully modernized stations in the system. It is recommended that similar provisions be incorporated in Stage 1 Central Subway improvements. In addition, all Central Subway stations would be equipped with public address systems.

STATIONS AND FARE COLLECTION

Fares currently are collected on board cars at all Green Line stations except those in subway. This practice would continue when the new No. 6 cars were placed in service.

Existing Brookline Village Station

It is recommended, however, that one of the high-volume stations, such as Brookline Village, be selected for installation of station fare-collection facilities to permit payment of fares before boarding. Several benefits would result from such an installation:

- Station dwell time and running time would be reduced;
- Various fare collection devices and station layouts could be tested before extending them to the entire Riverside Line.

The Authority is studying the benefits of automatic fare collection methods. The results of this study may be applicable to station facilities on the Riverside Line.

In conjunction with proposed track, roadbed and drainage improvement in station areas, low platforms would be repaired and lengthened to serve four-car trains. Radiant heaters would be installed in existing shelters. The estimated cost of this work is $175,000.

VEHICLE SUPPORT FACILITIES

It is recommended that complete shops and major repair facilities for the No. 6 cars be built at Riverside in Stage 1.

The Arborway and Watertown Lines, together with the maintenance facilities at their terminals would be abandoned. The Reservoir shops, although scheduled for upgrading in Stage 1, would be required to maintain PCC cars still operating on the Beacon Street and Commonwealth Avenue Lines.

The fleet of No. 6 cars to be purchased in Stage 1 would, therefore, be maintained in the new shop facilities at Riverside. This installation would be designed for later economic conversion to servicing of high-platform rapid transit cars.

ANTICIPATED BENEFITS AND LIMITATIONS

Inbound passenger traffic on the Riverside Line, as measured near the Fenway portal to the subway, reached a peak of 15,400 per day in 1967 and has declined since to approximately 13,400 in 1970.

The proposed Stage 1 improvements would reverse this drop in transit patronage. Even without further improvements beyond Stage 1, it is estimated that there would be a 40 percent increase in Riverside Line riders by the year 1990. This projected increase reflects growth in population and other factors including continued operation of express bus and commuter rail services. By 1990 the Riverside Line would carry about 19,000 daily inbound passengers, as shown previously on Figure 1-4.

Evaluation of recent MBTA express bus service on the Massachusetts Turnpike indicates that time saving has largely accounted for its success. About 43 percent of the passengers now using the Riverside express buses have been drawn from commuter trains and automobiles or are new riders. Another 34 percent have been diverted from other MBTA lines, this despite higher fares and poor downtown distribution for express bus patrons.

Faster and more dependable service on the Riverside Line might again make this line attractive for present express bus riders and motorists when the Turnpike becomes congested. Present railroad commuters might also turn to an improved Riverside Line if rail service were discontinued. Figure 5-13 shows anticipated reduction in running time expected to follow Stage 1 improvements.

The recommended Stage 1 improvements described earlier would bring the following benefits:

- Faster trips to the Central Area for transit riders and other commuters from the Western Corridor.
- Safer operation on all Green Lines.

- More dependable service and reduced waiting time due to closer adherence to schedules.
- More comfortable rides as a result of new roadbed, new cars and improved stations.
- More efficient use of transit vehicles due to better adherence to schedule and more uniform spacing of trains.
- Reduced pollution of the urban environment.
- Lower maintenance and operating costs from improvements in plant and rolling stock.

The major and more pressing needs of the Green Lines were examined. Possible improvements were studied and recommendations made.

The Consultant was engaged to investigate additional alternatives and to recommend an ultimate solution to the problems of the Green Lines. The findings of this study are reported in the following chapters.

ESTIMATED CAPITAL COSTS

The estimated cost of facilities described in this chapter is as follows:

Track and Roadbed		
Highland Branch	$3,410,000	
Central Subway and East Cambridge Viaduct	1,014,000	$4,424,000
Traction Power		4,367,000
Signals		
Track Circuits and Wayside Equipment	$5,025,000	
Interlockings	3,584,000	
Automatic Car Identification	807,000	
Automatic Train Dispatching	185,000	9,601,000
Communications		2,651,000
General Construction		175,000
Total Estimated Cost, Stage 1		$21,218,000

Additional Stage 1 improvements and attendant costs were developed by the Authority, and are described in Volume I:

- New rolling stock for the Green Lines.
- Improved clearances in the Central Subway.
- Additional emergency crossovers.
- Turnback facilities at Canal Street Station.
- Platform extension at Science Park Station.
- Acoustic treatment in subway and on elevated structure.
- Operational improvements on Huntington Avenue, Beacon Street and Commonwealth Avenue.
- Improved vehicle support capabilities at Reservoir and Riverside.

Prudential Center

Chapter 4
SYSTEMS I, II AND III

MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

Chapter 4

SYSTEMS I, II AND III

The previous chapter describes improvements proposed to be made immediately to the Riverside Line and the Central Subway.

Proposed new cars, modernized traction power and signal systems and better track and roadbed are all urgently needed at this time and should be followed as soon as possible by further upgrading of the system for maximum effectiveness.

Even after Stage 1 has been implemented, major problems in the Central Area would not have been solved. There would still be too many train movements in the Central Subway during peak periods. Headways of 60 seconds would continue to hold average speeds down to less than 10 miles per hour. Service would continue to be subject to undue disruption because of required operation on city streets. Vehicular cross-traffic at non-signalized grade crossings would continue to make it difficult to maintain schedules.

Other goals that should be sought after in additional staged improvements are the following:

- Utilization of potential crest speeds of the No. 6 cars;
- More sophisticated communications systems for surveillance and for monitoring service;
- Reduction in required double transfers in the Central Area;
- Reduction in travel time for Western Corridor patrons destined for the Central Area;
- Improved distribution to and between developing areas of the downtown Boston spine;
- Connection of the Western and Northeast Corridors through the Central Area;
- Realization of the Master Plan goal of extensions to the west and to the northeast;
- Reduction of air and noise pollution to enhance the urban environment.
- Easier accessibility to Logan Airport for persons originating along the Western Corridor and in the Central Area;
- Standardization of equipment in the Central Subway resulting in a safer transit operation; and
- Advancement toward balance between various modes of transportation.

SYSTEMS OBJECTIVES

In this report, a system is defined as an area-wide proposal that would achieve the broad objectives of this study, namely:

- Improvement of the quality of service in the Central Subway;
- Determination of the feasibility and desirability of connecting the Green and Blue Lines;
- Upgrading of track, power, and signal equipment as well as stations on the Riverside-Wonderland route; and
- Study of optimum locations for interconnecting rapid transit lines so that all cars could be maintained at a centralized maintenance and repair facility.

Three separate systems were formulated to achieve these broad goals. In addition, the systems would extend the effectiveness of Stage 1 by considering future improvements to achieve the benefits listed above.

These systems would use some of the route segments included in the Application for Federal Grant which was the basis for this study. Other alternatives might also achieve the goals of this study, and such possibilities are discussed in this report.

Each system is based on a different set of postulated future conditions. System I assumes the availability of the Boston & Albany Railroad (B&A) tracks between Fenway Park and South Station for transit use. System II assumes that this right of way would not be available to MBTA. System III assumes conversion of portions of the existing Central Subway to a high-platform rapid transit facility.

The systems are fully described in the remaining portion of this chapter, giving elements of routing, proposed improvements, anticipated benefits, and estimated costs, as well as limitations.

SYSTEM I

System I was designed on the assumption that the right of way of the Boston & Albany Railroad will become available for transit use east of Fenway Park. The Riverside Line would be removed from the Central Subway under System I and rerouted via railroad right of way and new subway to form a new rapid transit line through the Central Area.

The construction of System I would take place in stages at a currently estimated cost of $137,000,000.

The first stage was described in Chapter 3. Succeeding stages will be covered in subsequent sections of this report. The plan and profile of the ultimate development is presented in Volume III.

DESCRIPTION OF ROUTE

General

This system would remove the Riverside Line from the Central Subway, diverting it to existing B&A tracks.

In the ultimate stage, the Riverside Line would leave its present alignment near Fenway Park Station via a new connection to the B&A tracks. The new route would continue along these tracks parallel to the Massachusetts Turnpike to a new Back Bay Station adjacent to the proposed Orange Line.

A new subway would be constructed northeastward under the Boston Extension of the Massachusetts Turnpike, Columbus Avenue and Boston Common to a new Park Street Station. It would pass under Beacon Hill to connect with the Blue Line at existing Bowdoin Station.

Stage 1

The portion of the route that would be implemented in Stage 1 is described in Chapter 3.

Stage 2

In this stage the Riverside Line would be rerouted from the Central Subway. Beginning east of Longwood Station, the new alignment would parallel the existing Riverside Line and connect to the existing B&A tracks near Fenway Park. It would then continue eastward under Prudential Center and past Back Bay Station and stub tunnels for future subway under Columbus Avenue to a terminal at South Station.

Stage 3

The Riverside Line would continue to operate to South Station during this stage. The Beacon Street and Commonwealth Avenue Lines would terminate in a new North Station to be built under the existing Canal Street loop.

Due to elimination of the loop track at Park Street Station, the Huntington Avenue Line would be turned back at the Government Center Station loop or North Station.

Stage 4

A major change in routing during this stage would connect the Riverside Line to the Blue Line. This would be accomplished by extending new subway tunnels under the existing Massachusetts Turnpike from stub tunnels previously built at Back Bay Station in Stage 2. The route would continue northeastward in new subway under Columbus Avenue, extending in tunnels under the existing Boylston Street subway and Boston Common to a new Park Street Station complex. From here the alignment would curve northward under existing Red Line subway, passing deep under the east wing of the State House and continuing under Beacon Hill down Temple Street to connect with the existing Blue Line subway at Bowdoin Station.

The transit route between Back Bay Station and South Station established during Stage 2 could continue in operation.

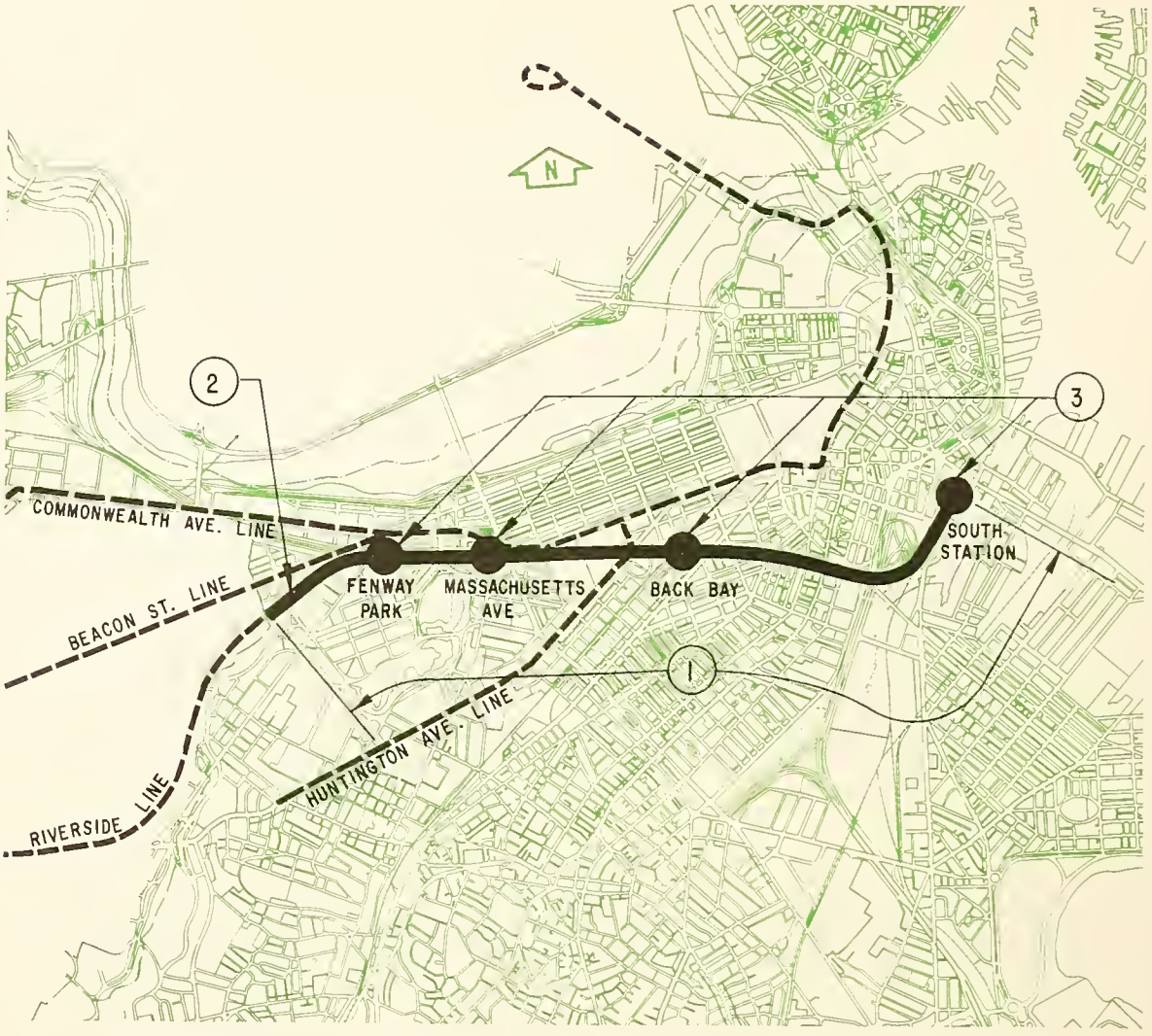


Figure 4-1
SYSTEM I
STAGE 2 PROPOSALS

1. Acquire B&A right of way from Fenway Park to South Station.

2. Construct track connections in Fenway Park area between the Riverside Line and newly acquired B&A tracks.

3. Construct new low-platform stations at Fenway Park, Massachusetts Avenue, Back Bay and South Station.

4. Reroute Riverside Line from Central Subway to B&A right of way between Fenway Park and South Station. Allow free passenger transfers to Green Line at Massachusetts Avenue to Red Line at South Station.

5. Continue to operate Beacon Street, Commonwealth and Huntington Avenue Lines in Central Subway.

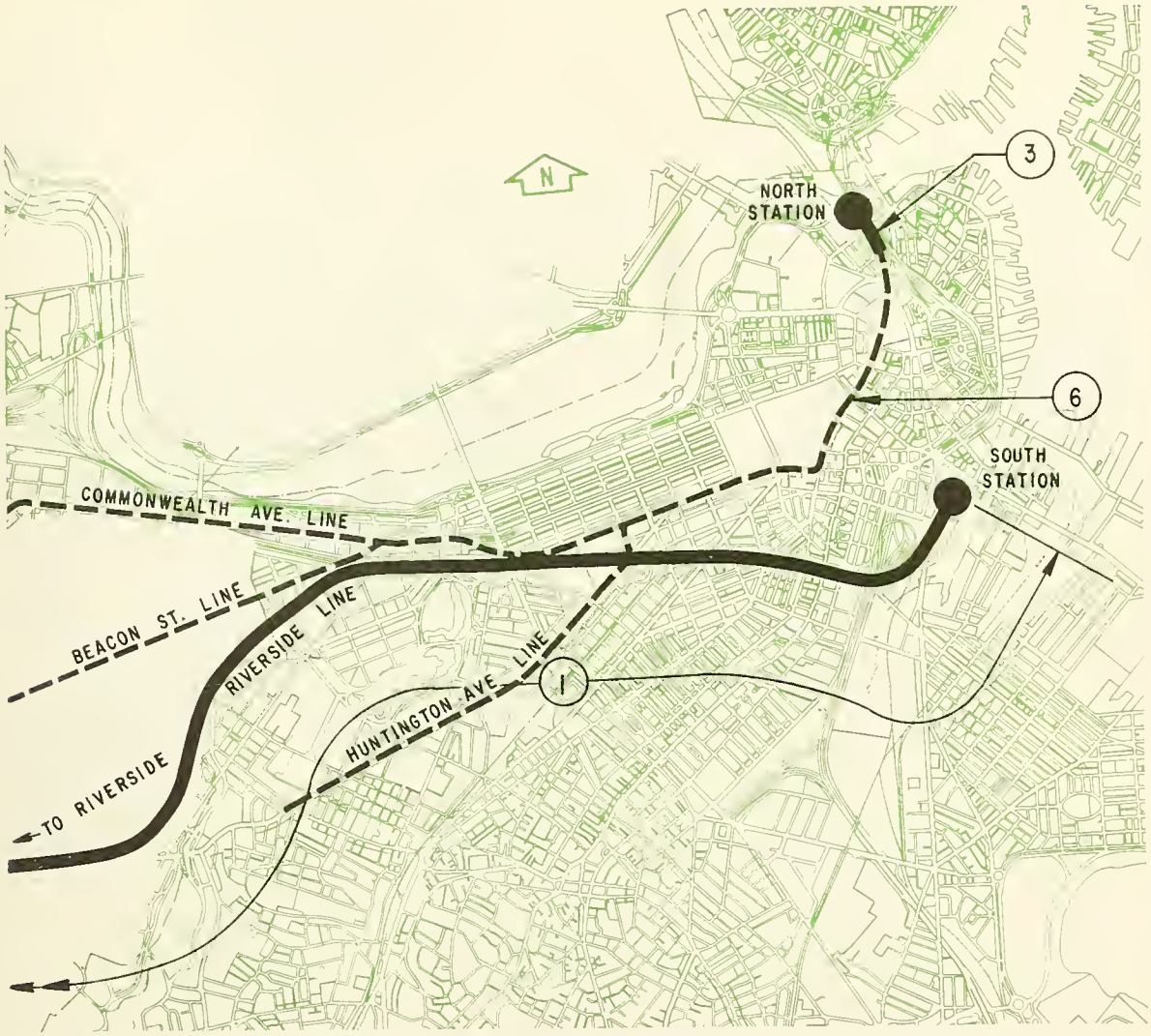


Figure 4-2
SYSTEM I
STAGE 3 PROPOSALS

1. Build new stations, converting platforms to high-level from Riverside to South Station. Build new fence along entire Riverside Line.

2. Convert shops and build a yard at Riverside for storage of high-platform rapid transit cars. Obtain Blue Line-type rapid transit cars for the Riverside Line.

3. Initiate high platform service, Riverside to South Station.

4. Build North Station Subway Station and an underground car storage facility. Build bus-to-rail transfer facility integrated with Orange and Green Lines at North Station. Remove elevated structure from Causeway Street.

5. Shift No. 6 cars from Riverside Line to Beacon Street and Commonwealth Avenue Lines, which would terminate at Canal Street.

6. Eliminate loop track at Park Street Station.

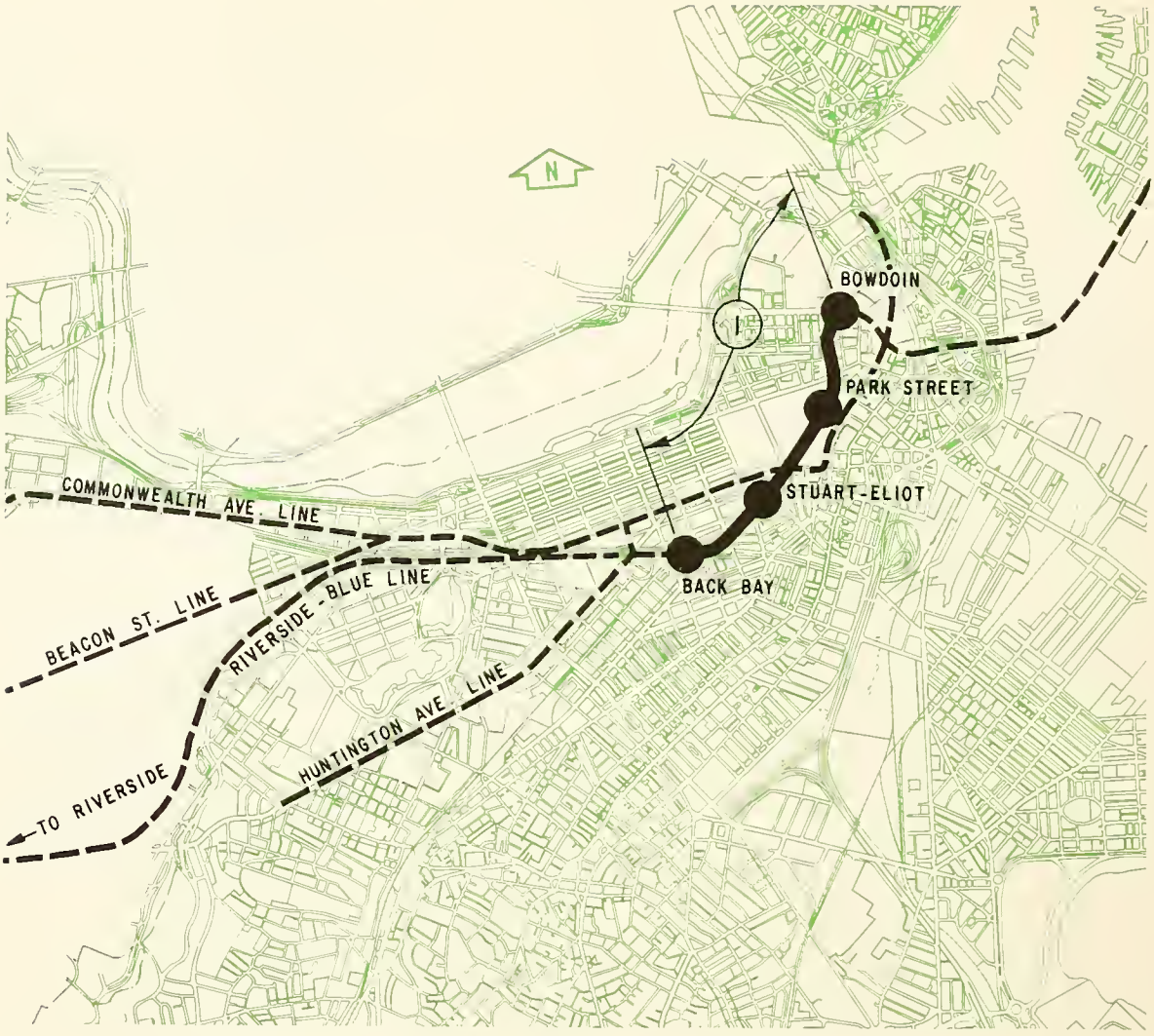


Figure 4-3
SYSTEM I
STAGE 4 PROPOSALS

1. Build new subway from Back Bay Station under the Boston Extension of the Massachusetts Turnpike, and continue via Columbus Avenue, Boston Common, and Beacon Hill to Bowdoin Station.

2. Begin high-platform rapid transit service from Riverside to Wonderland via former B & A tracks and Columbus Avenue Subway.

3. Evaluate demand for service to South Station and the need for extension from that point northward.

SYSTEM I

DESCRIPTION OF IMPROVEMENTS

Stage 1

Improvements proposed for implementation in Stage 1 are fully described in Chapter 3.

Stage 2

Track and Roadbed

Approximately 40 percent of all track replacement and roadbed improvement on the Riverside Line would have been completed in Stage 1. Remaining work to replace all track between Grove Street in Newton and Monmouth Court in Brookline would be completed in this stage. All track and ballast not replaced in Stage 1 would be renewed. No major realignment is proposed. Spirals on curves would be lengthened and superelevation increased to permit operation of No. 6 cars at 55 miles per hour wherever possible. Track profile would be adjusted and all track would be surfaced and aligned. Ditches would be cleaned and graded; hydraulic structures would be modified to restore proper drainage to track and roadbed.

At the completion of this stage, all wood ties would have been replaced with concrete ties between Riverside and Fenway Park. Further replacements of track between Fenway Park and South Station would depend on the condition of this section of track at the time of Stage 2 implementation.

Before the Riverside Line could be rerouted onto existing B&A tracks near Fenway Park, approximately 4,500 lineal feet of double track would have to beaconstructed between the existing Riverside Line near Longwood Station and the Charlesgate bridge over the B&A. Track connections to the incline into the Beach Street Subway would be preserved by installing turnouts from the Riverside Line near Monmouth Court.

Existing railroad tracks between Charlesgate and South Station would be used by the rapid transit line except where track construction would be made necessary by new work. At Back Bay Station a lower level station would be constructed. New track would be required between Huntington Avenue and Berkeley Street.

Track alignment and transit terminal facilities at South Station would depend on plans for reconstruction of that area now under development.

General Construction

Most of the construction activity in this stage would be in the vicinity of Back Bay Station. Excavation would take place below the level of the existing Massachusetts Turnpike and the proposed Orange Line tracks. In plan view, this excavation would be primarily in the constricted area between these two transportation facilities.

Two single-track inclines would be built in cut west of Dartmouth Street. Retaining walls would support the soil on these inclines to carry tracks to an elevation about 20 feet below existing track grade at the new Back Bay Station. The west end of the new center platform would extend under the existing Dartmouth Street bridge. Width of excavation would narrow from about 100 feet at the west end of the station to 40 feet at the east end. Subway construction would proceed eastward from Back Bay Station to prepare for future extension of tunnels northeastward under the Turnpike, including tunnel stubs near the Columbus Avenue Bridge. A temporary incline would be supported on permanent subway walls and rise to the B&A tracks near Columbus Avenue, as shown on Figure 4-4.

An alternative solution at Back Bay Station in this stage would be to modify the existing station site for transit operation. This would be a low-cost improvement in Stage 2. Future tunnels under the Turnpike and Back Bay Station area, however, would be built under traffic of the Riverside Line. This would be very difficult to stage and expensive to construct. If this alternative were selected, future construction in the Back Bay area would be simplified if it were possible to reroute the Riverside Line through the Central Subway, or by transferring passengers to the Central Subway at Auditorium Station during construction. The Authority should determine whether it would be feasible to temporarily reintroduce Riverside Line traffic into the Central Subway at Beacon Junction.

A second alternative solution at Back Bay Station would be to transfer Riverside Line passengers to the Orange Line. This plan is described more fully in the next chapter.

The Back Bay Station layout was based on the following assumptions:

- Penn Central Railroad operations will be discontinued in this area.

- Orange Line relocation will take place as shown on plans received from MBTA in February 1969. These plans show a three-track Orange Line Station occupying all of the right of way of the New York, New Haven and Hartford Railroad branch of the Penn Central Railroad at Back Bay Station. In accordance with

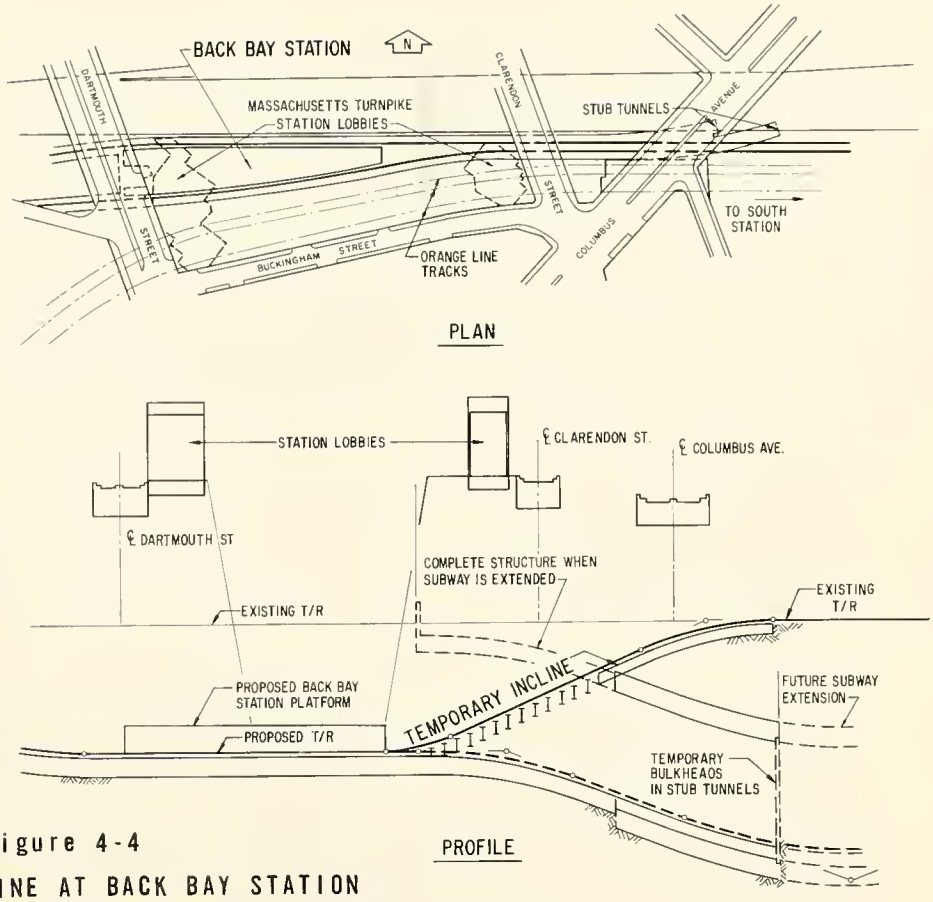


Figure 4-4

TEMPORARY INCLINE AT BACK BAY STATION
SYSTEM I, STAGE 2

instructions from MBTA, it was understood this station could not be altered.

- The John Hancock Garage over the Turnpike in this vicinity will be built essentially as shown on preliminary plans made available when this study was started.

- The Dartmouth and Clarendon Street bridges will not be totally reconstructed.

Several of the difficulties that would be encountered during construction are as follows:

- The site has very poor accessibility for construction activities.

- The existing soils conditions of high water table and silty soil might result in subsidence of adjacent structures during construction.

- Substructure units supporting Turnpike ramps and Dartmouth Street, Clarendon Street and Columbus Avenue bridges would have to be underpinned or rebuilt. The Hancock Garage and new transit stations might also require additional support due to Green Line construction.

Stations

Four new stations with low platforms would be constructed during this stage. They would be at Fenway Park, Massachusetts Avenue, Back Bay and South Station.

Station construction would be of a temporary nature with the exception of Back Bay Station. Platforms would be at track level, 200 feet in length, with a minimum width of eight feet. Passenger shelters on the platforms would have radiant heaters, good lighting, and a high degree of visibility for surveillance.

Access to Fenway Station platforms would be from Brookline Avenue bridge; to Massachusetts Avenue Station platforms from Massachusetts Avenue. Fare collection at both stations could be either on board cars as at present or at agents' booths on the platforms. At Back Bay Station, access to platforms would be through proposed Orange Line lobbies at Dartmouth and Clarendon Streets. Access and precise location of South Station facilities are being considered in urban renewal plans being developed by others.

Passenger transfer would be possible at each of the four stations under consideration. Fenway Park Station has poor potential in this regard, but moving sidewalks under the Turnpike to Kenmore Station have been considered. Massachusetts Avenue Station would afford Riverside Line riders access to Central Subway and to that portion of the Green Line to be retained by means of a free transfer to Auditorium Station. Riverside Line riders could transfer to the Orange Line at Back Bay Station; they could transfer to the Red Line at South Station.

Traction Power

A new catenary system with supplemental feeders as required would be installed for the new section between Fenway Park and South Station. The catenary system would be suitable for both trolley pole and pantograph operation.

This new route between Fenway Park and South Station would be fed from existing substations during this stage as follows:

- The section between the existing Fenway Park Station and the new Fenway Park Station would be tied to the present Feeder Section 94 now fed from existing Coolidge and Newbury Substations. New feeder ties would be made at existing Fenway Park Station.

- The section between the new Fenway Park Station and new Massachusetts Avenue Station would be tied to the present Feeder Section S-5 now fed from existing Newbury Substation. Feeder tie connections would be made between existing Auditorium Station and new Massachusetts Avenue Station using Massachusetts Avenue underground conduits.

- The section from the new Massachusetts Avenue Station to the point where Tremont Street crosses the B&A right of way would be tied to the present Feeder Section S-9 now fed from existing Newbury and Central Substations. Present Section S-9 feeders from Newbury Substation would be extended from existing Auditorium Station to the new Massachusetts Avenue Station via Massachusetts Avenue underground ducts. The present Section S-9 underground feeder from Central Substation would be tapped at Dartmouth Street and extended to new overhead at that point.

- The section from Tremont Street to South Station would be tied to the present Feeder Section S-7 now fed from Central and Dewey Substations. Present Section S-7 underground feeders from Central Substation would be tapped at Washington Street and extended to new overhead at that point. Existing Section S-7 feeder from Dewey Substation would be tapped at the substation and extended to the new overhead at South Station.

Existing Feeder Sections 94, S-5, S-9 and S-7 would remain in place and continue to feed those portions of the Beacon Street, Commonwealth Avenue, and Huntington Avenue branches of the Green Line system operating through the Central Area Subway in this stage.

Power requirements in Stage 2 would be essentially the same as in Stage 1; therefore, the arrangement of new and existing substations as proposed in Stage 1 would adequately serve the peak hour power demands of the combined operations of new No. 6 cars and existing PCC cars during this stage.

Signals and Communications

The signal and communication systems as described under the discussion of Stage 1 would be extended in this stage to the new route between Fenway Park and South Station. An automatic train dispatcher would be installed at South Station.

If, at this stage, the Dewey Control Center is operational, the Riverside Line signal, communications, power and supervisory control systems would be linked to this facility.

Rolling Stock and Operations

The No. 6 cars purchased and placed into service on the Riverside Line in Stage 1 would be diverted from the Central Subway to South Station via B&A right of way.

Huntington Avenue Line No. 6 cars would continue to operate in the Central Subway through the existing Copley Junction, intermingled with PCC cars of the Beacon Street and Commonwealth Avenue Lines.

Vehicle Support Facilities

Maintenance, repair and storage facilities for PCC and No. 6 cars described in Stage 1 would be used during this stage.

The track connection between the Central Subway and the Riverside Line near Park Drive would be used for major maintenance and repair of PCC cars in the Riverside shops.

If the track connection between the relocated Orange Line and the proposed Dover Street yard would have been constructed, it could also be used to link the Riverside and Orange Lines east of Back Bay Station. This link would allow Mattapan trolleys to be repaired at Riverside or, conversely, PCC and Riverside No. 6 cars could be repaired at Dover Street, thereby introducing flexibility into the vehicle maintenance program.

Stage 3

Track and Roadbed

A new yard at Riverside would be built to store and service new rapid transit cars that would begin operating on the Riverside Line in this stage. Construction of this yard would be staged to minimize interference with day-to-day activities in the existing Riverside yard and station.

The new yard would occupy existing MBTA property west of Grove Street in Newton, but additional property would be required along the Charles River and the right of way of the Newton Lower Falls Branch of the Penn-Central Railroad. It is assumed that the operation of this Branch would have been discontinued earlier. By constructing the yard at a higher elevation and building a tunnel for this Branch, however, railroad operation could be retained.

The new yard layout shown on Exhibit 4 in Volume III was designed for the storage of 100 No. 5 Cambridge cars in four- and six-car trains. Track connections between the new shops built in Stage 1 and the existing yard would be retained until the new yard was operational. At that time, existing yard tracks would be removed and the new yard would be completed. Recommended track connections between this yard and the Western Corridor will be described in Chapter VI.

Portions of track on the Riverside Line would have to be realigned because high platform cars would be used. Segments of track in the vicinity of high-platform stations would be re-built with minimum radii of 4000 feet. See station criteria in the Appendix for details. Track centers would be increased to a minimum of 13'-0".

Locations and approximate lengths of double track to be shifted in this stage are as follows:

Station	Length of Double Track in Feet
Waban	1000
Newton Highlands	900
Chestnut Hill	1800
Longwood	3500

The simple catenary and support system built in Stage 1 would be shifted and reconstructed to correspond to new alignment and to new station construction.

Underground storage tracks would be built in the North Station area to be used by the new double-ended No. 6 cars that would be transferred from the Riverside Line to the Beacon and Commonwealth Lines later in this stage. See Exhibit 61 for details of this storage facility. Although this exhibit is introduced in connection with System III, it applies to all systems studied.

The loop track and the two outer tracks at Park Street Station would be removed. Huntington Line trains that formerly used the loop would then operate on the realigned center tracks through Park Street Station and turn back via the Government Center loop or at the new North Station terminal.

General Construction

Construction work in this stage would include new stations between the Riverside and South Station terminals, reconstruction and modernization of the Park Street and Boylston Stations, and extensive underground construction at the new North Station terminal.

The following criteria guided functional design of new stations:

- Passenger movements to be grade-separated from train movements for maximum safety.
- Facilities to be installed for collecting fares in station lobbies rather than on board trains.
- Station design to include such amenities as escalators, shelter from inclement weather, radiant heaters, and attractive environment.

The application of these concepts to stations on the Riverside Line will be discussed below, with particular emphasis on several of the major stations.

The new Riverside Station would lie just east of Grove Street. The station platform and tracks would be supported on a structure over a station lobby at street level. Buses would loop around the station, discharging passengers on the south side and receiving them on the north side of the lobby. The open space under the structure would afford passengers maximum visibility and freedom of movement. A kiss-'n-ride loop close to the station would serve transit riders delivered and picked up by private automobiles. A 1500-car parking lot would serve park-'n-ride transit patrons. Exit Only stairs would lead from the west end of the platform above to the parking lot level. This arrangement would separate park-'n-riders from bus riders and kiss-'n-riders, and would speed the flow of passengers through the station during the evening rush hour.

Most of the new stations on the Riverside Line would have lobbies adjacent to bridges over the track. Passengers would enter the lobby from the sidewalk on the bridge, pay a fare, and proceed down a stairway or reversible escalator to either the inbound or outbound side platform.

Stations that would have such a layout are:

Woodland
Waban
Chestnut Hill
Reservoir
Brookline Hills
Brookline Village
Fenway Park
Massachusetts Avenue

Newton Highlands, Newton Center and Longwood Stations would have lobbies at mid-platform with access to the lobbies from streets paralleling the tracks.

Back Bay Station, which would be built in Stage 2, would be modified in Stage 3 by replacing low-level platforms with high-level platforms and modifying escalators accordingly.

Platforms at South Station would be reconstructed to high level, but additional station modifications would remain subject to redevelopment plans for this area.

Traction Power

To provide the additional power and voltage regulation required for the operation of the new high-level rapid transit cars on the Riverside Line between Riverside and Massachusetts Avenue, new substations, in addition to those installed in Stage 1, would be built at Brookline Village and near the new Fenway Park Station. The present Cooks Junction substation with two 1000 kw mercury arc rectifiers, and fed from 25-cycle AC power supplied by the MBTA generating stations, would be rehabilitated and increased in capacity. New solid state, silicon-diode-type rectifier units and associated rectifier transformers and gear as required would be installed, and the substation fed from new 60-cycle AC power supplied from a local utility company source. The changeover of Cooks Junction substation would be made while low-level cars were still in operation, at which time the peak demand load on the station would be within the limits of one of the existing rectifier units.

The section of the Riverside Line between Massachusetts Avenue and South Station would be fed from the new Back Bay substation proposed for the new Orange Line extension and the new Dewey substation proposed for the Orange and Red Lines. One rectifier unit and associated equipment would be required in the new Back Bay substation in addition to the two 3000 kw units proposed for the Orange Line. It is assumed that during this stage neither the Orange, Red nor Riverside Lines would be operating under ultimate headways and that the capacity of the new Dewey substation as proposed for the Orange and Red Lines would be adequate to handle the additional load of the temporary Riverside Line operation to South Station.

With the removal of all Riverside Line power loads from existing Coolidge, Oak Square, Newbury, Central, Dewey and North Station substations, they would have sufficient capacity to meet the increased peak hour loads on the Commonwealth Avenue, Beacon Street and Huntington Avenue Lines caused by the transfer of the new No. 6 cars to these lines from the Riverside Line.

Existing direct suspension overhead contact wire distribution systems for the surface street operations of these three routes would be rehabilitated by installing new contact wire throughout and replacing support

poles, pole brackets and span wires where necessary to provide for smooth power pickup. Feeder capacities in some sections of these routes would have to be increased to maintain voltage levels within prescribed limits.

It would then be possible to remove the temporary feeder ties installed in Stage 2 from the existing feeder Sections 94, S-5, S-9 and S-7 to provide power to the overhead catenary system for the new Riverside Line between Fenway Park and South Station. Catenary system for this section would then be fed from the new Fenway Park, Back Bay and Dewey substations.

The existing simple catenary overhead distribution system between Riverside and South Station would be adjusted and dressed to minimize wear on pantograph collector shoes.

The existing direct suspension overhead system between Canal Street and Lechmere would be removed.

Signals and Communications

The signal system installed in Stages 1 and 2, and fully described in Chapter 3, would remain in operation during this stage.

New interlockings would be installed at the Riverside and North Station yards.

The multi-speed signal system with overspeed control that would be installed on new Blue Line-type cars would be similar to the system being used on the New No. 6 cars.

Telephone communications and supervisory control would be installed between Riverside and Fenway Park, and would be linked to the Dewey Control Center in this stage. Similar installations in the Central Subway made in Stage 1 would also be connected to this facility.

Automatic train dispatchers would be installed at Riverside and North Station.

Rolling Stock and Operation

A new fleet of high-platform rapid transit cars, similar to Blue Line cars and capable of eventual operation through the East Boston tunnel, would be placed in service between Riverside and South Station. Shops at Riverside would be modified to permit servicing of these cars.

New cars would be equipped for dual traction power pickup, i. e., pantograph for overhead power distribution on surface and contact shoe for third rail power distribution in subways.

Blue Line Car

Car-borne signal equipment would consist of a multi-speed cab signal system with overspeed control. Provision would be made for future automatic train control operation.

PCC cars still operating on the Beacon, Commonwealth and Huntington Lines would be retired from service by the transfer of No. 6 cars from the Riverside Line. The potential of these cars for high speeds with even greater safety would be realized if traffic control were instituted and grade crossings were eliminated as recommended in correlated CASS studies of the Beacon and Huntington Lines. The grade crossing problem on Commonwealth Avenue remains to be studied. For a general discussion of ways to increase the operating efficiency of grade crossings on Commonwealth Avenue see the Appendix.

Once the PCC cars were removed from operation in the Central Subway, the higher design speeds of the No. 6 cars could be realized. The resultant need for improved riding quality would necessitate additional realignment and surfacing of track.

The existing feeder bus lines serving the Somerville Corridor and terminating at Lechmere Station are being studied by others. Preliminary results of this study indicate that rerouting of these bus lines to the Haymarket-North extension of the Orange Line and to the Red Line would provide better service than continued busing to Lechmere or to

the proposed North Station terminal at the existing Canal Street loop (Exhibit 128, Volume III.) However, bus transfer facilities have been proposed in the North Station development pending final results of the Somerville study.

Insufficient justification could be found for rehabilitating the East Cambridge viaduct and the Causeway Street elevated structure. A subway between Haymarket Station and the viaduct to replace the elevated structure was studied but found not to be warranted.

Stage 4

Alignment

The final project to join the Green and Blue Lines through the Central Area would be construction of a subway between Back Bay and Bowdoin Stations.

This subway would begin east of Back Bay Station where stub tunnels would have been built in Stage 2. The alignment of the twin tunnels under the Boston Extension of the Massachusetts Turnpike would follow a reverse curve into Columbus Avenue. This alignment was selected to avoid extensive underpinning or reconstruction of the Columbus Avenue bridge and attendant interference with traffic on the Turnpike. The profile would have a low point under the Turnpike and would rise toward Columbus Avenue where the Stuart-Eliot Station would be close to the street surface.

The alignment would continue northeast on Columbus Avenue toward Park Street Station. The subway tunnels would pass under the existing Boylston Street subway and Boston Common, curving slightly to the north to a new Park Street Station adjacent to the existing station. The profile of the subway under the Boston Common and Beacon Hill would be deep to ensure that the attractive appearance of the area would be preserved.

The subway between Park Street and Bowdoin Stations would pass under the existing Red Line Subway, curve northward, pass under the east wing of the Massachusetts State House, and continue under Temple Street to join with the existing Blue Line Subway at Bowdoin Station.

General Construction

Subway design between Back Bay and Bowdoin Stations would be divided into four major sections based on assumed methods of construction.

Under the Turnpike, the subway would consist of twin circular tunnels, each about 850 feet long, extending from stub tunnels built under the

south edge of the Turnpike in Stage 2. The roadway profile of the Turnpike at the point of crossing is at mean sea level. To resist the uplift forces of ground water, the Turnpike pavement is more than three feet thick. In addition to bracing and underpinning the slab, provision would have to be made to keep the 48-inch main drain of the Turnpike in operation.

Major reconstruction or underpinning of the timber pile-supported Columbus Avenue bridge piers has been avoided to minimize interference with Turnpike traffic. However, the south spans and support structures of the Clarendon Street and Columbus Avenue bridges would be reconstructed.

The section of subway under Columbus Avenue between Isabella and Boylston Streets would be built by the cut-and-cover method. Columbus Avenue is a wide street which, if extended northeast across the Common, would pass directly through Park Street Station. Subway construction would be feasible and economical, especially in light of redevelopment plans for this area.

The Boston Redevelopment Authority plans for urban renewal of this area indicate that the importance of Columbus Avenue as a traffic artery will be diminished in the future. Under these plans, Columbus Avenue would become a one-way, southbound service drive between Stuart and Eliot Streets, terminating at Stuart. The 30-story Eastern Gas Associates Building already under construction on the northwest side of Park Square encroaches on the present right of way of Columbus Avenue in accord with the revised street pattern for this area. These plans make Columbus Avenue an attractive route for a subway.

Twin tunnels would extend about 3,000 feet from the Park Square area to the north side of the State House, passing under Boston Common, the existing Red Line subway at Park Street Station, and Beacon Hill. The existing Boylston Street subway structure would be underpinned or reconstructed at Park Square and supported on new foundations. This would permit subsequent construction of the proposed tunnels under the reconstructed subway without interrupting service in the Central Subway.

Tunnels probably would be constructed primarily by use of power-driven tunnelling machines. Hand-mining would probably be the best method of excavating the tunnels through the Park Street Station since they would be only 440 feet long and have a larger diameter than line tunnels.

The tunnels would be built in sand and gravel at Park Street Station. Clay soil would be encountered north of this area. Ground water control during construction would be necessary since the tunnels would be well below the ground water table.

The deep profile under buildings along Park Street and under the State House would avoid the necessity of extensive underpinning that might be required if a shallower profile were used. With the deep profile, underpinning of the existing Red Line subway might become necessary to preclude settlement due to tunnelling below.

The remaining 800 feet of subway between Derne Street and Bowdoin Station would be built by the cut-and-cover method. The proposed curvature of the alignment at the junction with the Blue Line would be sharper than desirable. The existing 75-foot radius might be flattened somewhat by reconstruction of the curve under New Chardon Street. However, the existing Bowdoin Station platform restricts the amount by which the curve could be flattened, and speeds at this location would continue to be restricted.

Stations

The proposed Stuart-Eliot subway station would be built under Columbus Avenue adjacent to the Statler-Hilton Hotel. Stairways and escalators would lead down from both sides of Columbus Avenue to the station lobby below the street. From this mezzanine level, passengers would pay fares and proceed down another flight of stairs and escalators to the center platform. This station would be in the recently announced $500 million Park Square Area development.

The Park Street Station is proposed to have end-loading of the Blue and Green Line platforms to encourage maximum dispersal throughout the station of the large numbers of people expected to use it.

Two above-ground structures to house fare collection operations would serve Park Street Station. One would be sited in Boston Common at the intersection of Park and Tremont Streets, replacing the two existing kiosks. This would be the major station entrance, furnishing direct access from the surface to Green Line platforms. A second flight of escalators and stairways would take passengers from the Green Lines level directly onto either side platform of the Red Line. The Red Line center platform would be removed to allow widening of each side platform within the existing structure to accommodate transfers and through movements between Red and Blue Lines. Realignment of Red Line tracks would ease the reverse curves at each end of the station. A new stairway and escalator from each side platform of the Red Line would lead down to a passageway over the new Blue Line Station. From this passageway, each side platform of the two Blue Line station tunnels would be accessible by means of another set of stairways and escalators.

A second fare collection structure would be built on the east side of Tremont Street south of Temple Place. It would serve the Green and

Park Street Station Kiosks

Visitors' Information Center in Boston Common

Blue Lines directly through a passageway running under the Green Line and over the Blue Line. From this passageway, a stairway and escalator would rise to each side platform of the Green Lines, and similar facilities would connect with each side platform of the Blue Line.

Trackwork

All trackwork installed in the new subway would be fastened directly to the concrete invert.

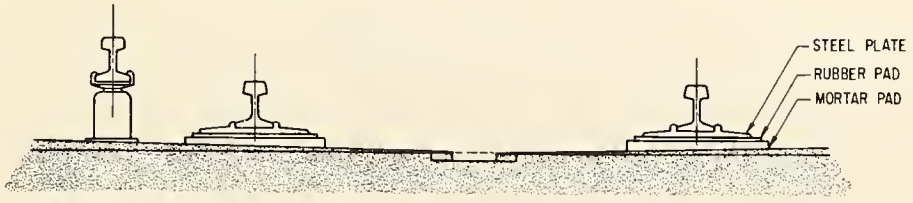


Figure 4-5

PROPOSED TRACK FASTENED TO CONCRETE INVERT

Traction Power

The traction power distribution and current collection system from Riverside to Bowdoin on the Blue Line via the newly-constructed subway would be as follows:

- Riverside to Back Bay Station--Pantograph operation from an overhead catenary system as in Stage 3.

- Back Bay Station to Bowdoin Station--Collector shoe operation from a third rail system installed in this stage.

Changeover from overhead to third rail current collectors would be made during station stops at Back Bay and, as at present, at Maverick.

Power and voltage regulation requirements for the section between Riverside and Massachusetts Avenue would be the same as in Stage 3; therefore, no changes or additions would be necessary for the ultimate operation under this stage.

The section of the new route between Massachusetts Avenue and Stuart-Eliot Stations would be fed from the new Back Bay substation proposed for the new Orange Line extension.

The capacity of the Back Bay substation, including the rectifier unit and associated equipment added for the Riverside operations in Stage 3, would be adequate to handle the additional power requirements for the ultimate Riverside-Bowdoin operations over this section of the route.

The section between Stuart-Eliot and Bowdoin stations would be fed from the new Dewey substation proposed for the new Orange and Red Line systems. Two rectifier units and associated equipment would be required in the new Dewey substation in addition to the two 3000 kw units proposed for the Orange Line and two 3000 kw units proposed for the Red Line. A feeder cable would be installed from the new Dewey substation to serve this section; it would run from the substation to Park Street station via the Red Line subway.

Train operations as well as power and voltage regulation requirements for the Commonwealth Avenue, Beacon Street and Huntington Avenue Lines would be the same as in Stage 3; therefore, no changes or additions would be necessary for ultimate operation under this stage.

Signals and Communications

The signal and communication systems as fully described under the discussion of Stage 1, would be extended in this stage to the new subway between Back Bay and Bowdoin Stations.

Rolling Stock and Operations

It is assumed that the type of cars purchased for the Riverside Line in Stage 3 would replace all old cars still in operation on the Blue Line at the same time.

ANTICIPATED BENEFITS AND LIMITATIONS

The tangible benefits to be derived from improvements described in this chapter would include increased passenger volumes, better distribution at downtown destinations, reduced travel times and improved transfer capabilities. The Authority and its traffic consultant, Peat, Marwick, Mitchell & Co., have analyzed the patronage that would occur in 1990 on each of the systems studied. Systems were compared with each other as well as with the MBTA system as it existed in 1963 when the Home Interview Survey was made. The comparisons were based on the traffic estimated to be generated in each corridor under various plans. The results of the downtown distribution patterns under each system were also analyzed.

In his report to the Authority, the traffic consultant listed limitations that were inherent in his study. Among these were the following:

- Intra-downtown transit trips were omitted.
- More complete data regarding modal split relationships, estimates of line volumes and distribution at destination, and ridership impacts due to changes in the downtown network would have been desirable.

The traffic analysis is considered useful for comparing alternatives in the routing of transit lines through the Central Area.

The following general traffic forecasts emphasize the urgency of a long-range solution to the problem of the Green Lines:

- Volume on the Riverside Line near the Fenway Portal would increase from 15,400 in 1967 to over 40,000 per day in each direction by 1990, assuming no parking restraints at transit stations.
- Volume in the Central Subway would approach 60,000 per day in each direction by 1990 compared with about 51,000 in 1964.
- Corridor-to-downtown trips would increase from 156,000 per day in 1963 to an estimated 230,000 in 1990--a projected increase of nearly 50 percent. An equal number of passengers would make return trips each day.

- About 113,000 corridor-to-corridor trips would pass through the Central Area network each day in 1990, compared with 63,000 in 1964. This would represent an increase of about 80 percent.

- Transfers in the Central Area would nearly double between 1964 and 1990 to almost 270,000 per day.

- Total daily Central Area system traffic would increase 60 percent--from 440,000 in 1964 to an estimated 700,000 in 1990. This is the combined total of passengers boarding, alighting and transferring at 22 downtown stations.

The average number of transit riders per day that would move in each direction on System I in 1990 is shown in Figure 4-6.

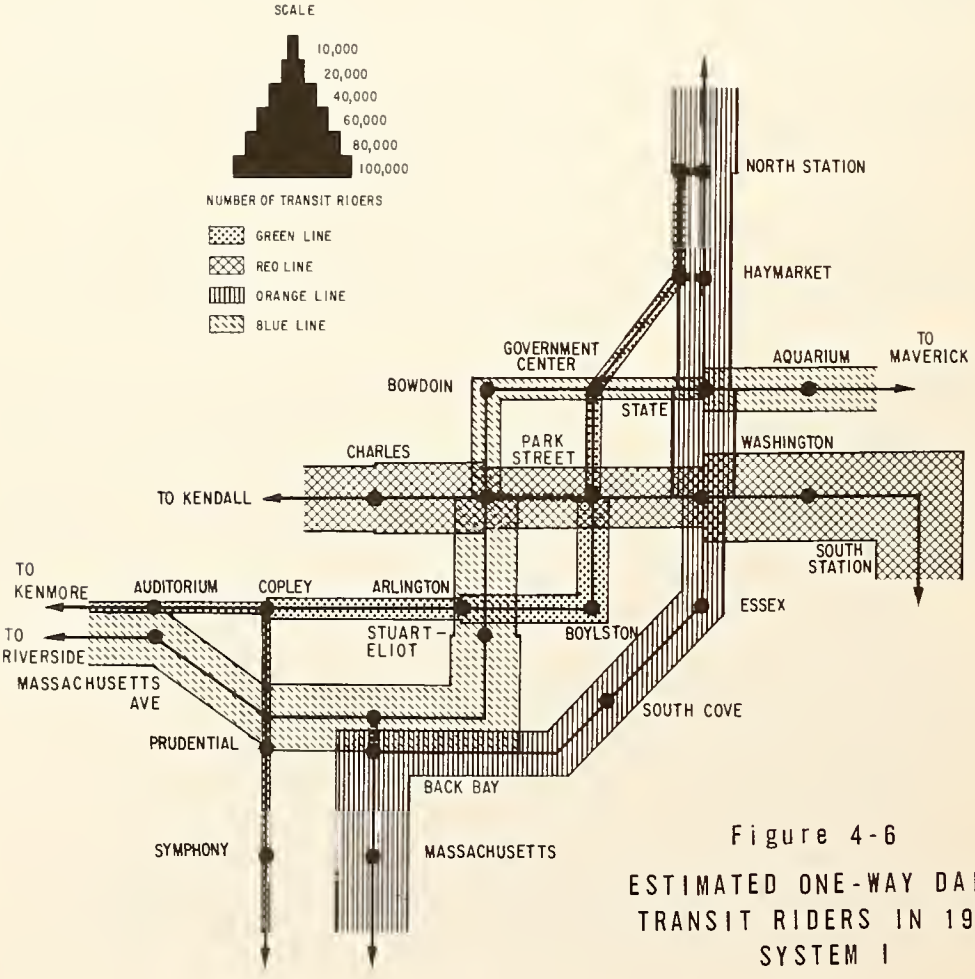


Figure 4-6

ESTIMATED ONE-WAY DAILY TRANSIT RIDERS IN 1990 SYSTEM I

Connection of the Riverside Line to the Blue Line would better serve over 17,000 daily riders in each direction who would continue through Bowdoin Station without transferring.

Figures 1-3 and 1-4 in Chapter 1 show the daily downtown travel time saved on each transit line and the total daily downtown travel time saved on the overall Authority System with the implementation of System I, II or III as compared to that resulting from implementing Stage 1 improvements only.

Green Line passengers would save 360,000 minutes per day or 1,800,000 hours annually while Blue Line riders would benefit by some 300,000 hours annually. Total times saved for the entire system would amount to over 11,000 passenger hours per day or 3,300,000 hours annually. The annual dollar value of travel-time savings to the rider resulting from the implementation of the long-range recommendation would be a substantial benefit.

Additional indirect economic benefits such as improved employment opportunities, increased property values and added tax base would make a long-range solution even more advantageous.

Figure 4-12 shows the passenger volumes in 1990 assuming no changes in alignment had been made beyond Stage 1. This figure is based on the assumption that there would be no change from the present Green Line system configuration. It also assumes that the low-platform cars and the large number of Green Line branch routes planned for operation in the Central Subway in Stage 1 could give the same level of service as the improved cars and reduced number of lines in System I. The values shown on Figure 4-12 appear to be excessive since the service levels assumed in its formulation probably could not be attained with low-platform No. 6 cars and with all four Green Lines operating in the Central Subway. Total passenger volumes were held constant in determining travel time performance of each system, when, in fact, the ridership levels would vary for each system depending on system performance.

Estimated daily station entries in 1990 for System I are shown in Figure 4-7. For comparative purposes, Figure 4-13 illustrates station entries per day that might occur in 1990 if only Stage 1 improvements were made.

The daily boarding volume at Bowdoin Station would be about 10,000 compared with 4,000 if no connection were made between Park Street and Bowdoin Stations. This connection would also result in reduced patronage of the Charles, Government Center and Haymarket Stations.

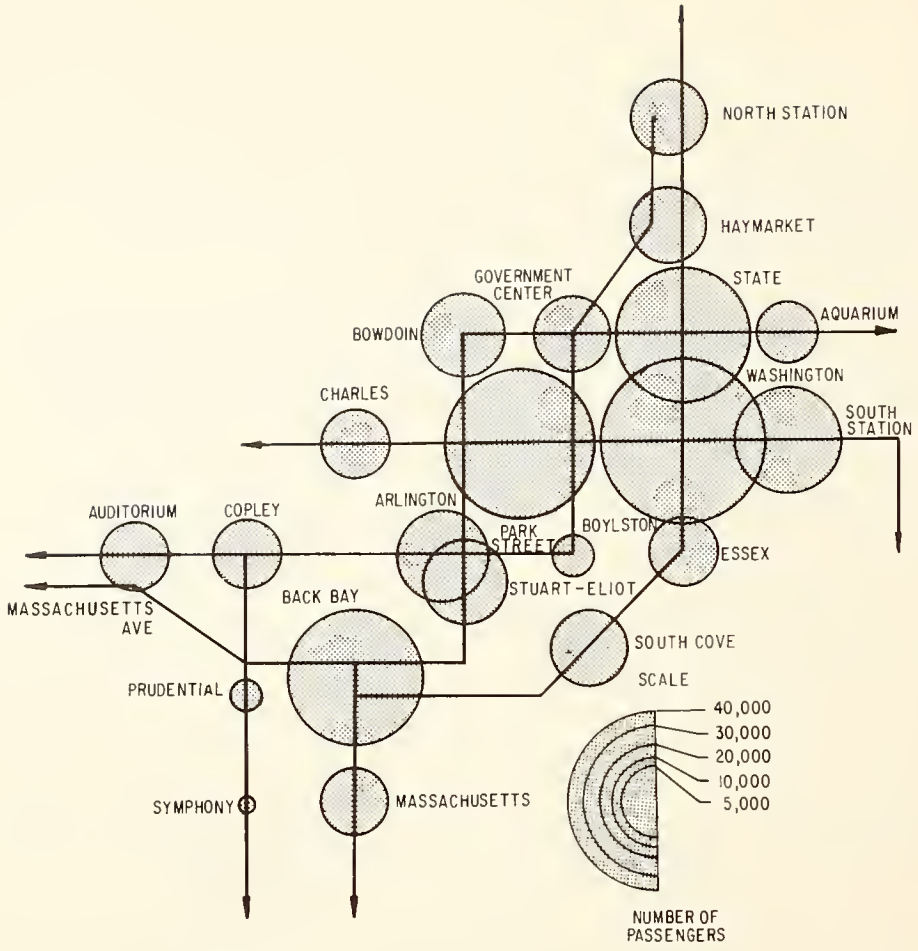


Figure 4-7

ESTIMATED DAILY STATION ENTRIES IN 1990
SYSTEM I

Improved service to about 10,000 riders supplied by the new Stuart-Eliot Station in the Central Business District would result in fewer passengers entering at Copley, Arlington and Boylston Stations.

Park Street Station entries would rise from 23,000 to 29,000 daily, due primarily to diversions from Washington Station. The easy transfer at Back Bay Station between the Blue and Orange Lines apparently would better serve people bound for the Park Street Station area.

One of the major benefits of System I route changes would be the easier transferring between transit lines. This is illustrated by Park Street Station, Figure 4-8, where total number of daily transfers would increase from 50,000 in 1964 to about 108,000 in 1990, an increase of 116 percent.

Transfers at Back Bay Station would approximate 49,000 per day. See Figure 4-10.

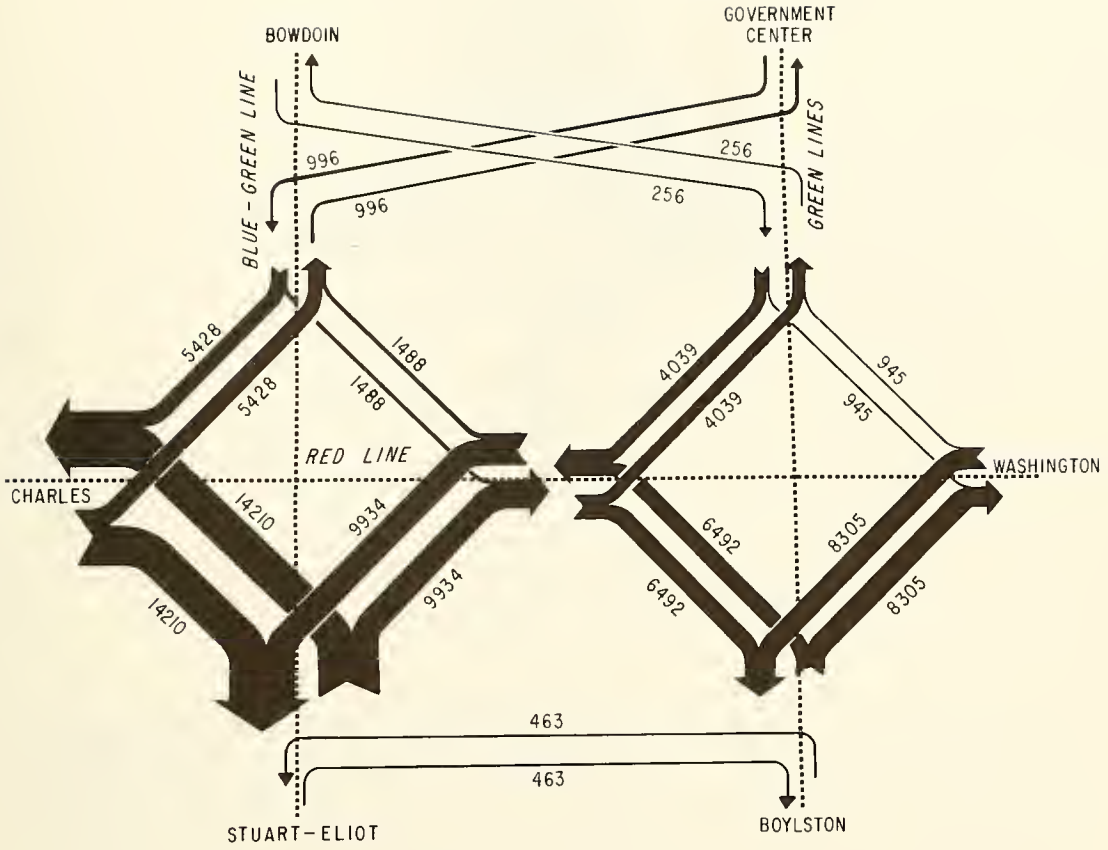


Figure 4-8

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM I
Park Street Station

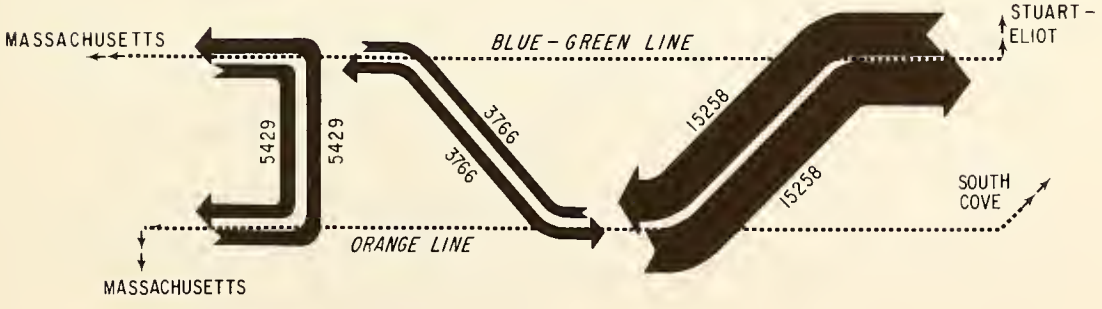


Figure 4-9

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM I
Back Bay Station

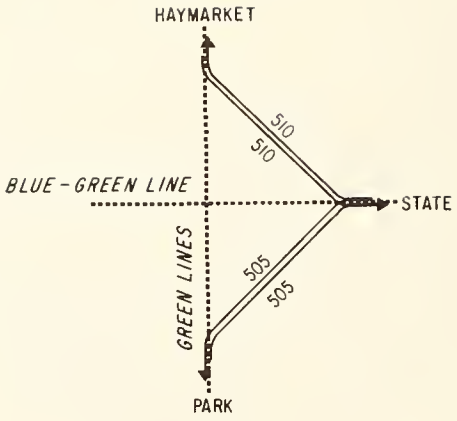


Figure 4-10

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM I
Government Center Station

The convenient transfer between the Blue and Orange Lines at this station would have the effect of bringing the passenger closer to his final destination. This would be most apparent in System I, which would have the shortest average downtown walk time of any system studied--about 11 percent less than would result from making Stage 1 improvements only. System I also exhibited less transfer and waiting times than the other systems studied.

Government Center Station would be much less used for transfer movements between the Blue and Green Lines in System I, as shown in Figure 4-10. Transfers at this station would drop from 12,000 in 1964 to an estimated 2,000 in 1990 for System I. If only Stage 1 improvements were made and the Blue-Green connection were not built, the number of transfers would increase to 22,000 at this station. The connection between Bowdoin and Park Street Stations, however, would eliminate the need for most of these transfers since riders moving between the Blue and the Red Lines would have to transfer only once.

The Park Street-to-Bowdoin connection would also hold the number of transfers at Washington Station at 49,000 daily; otherwise, the demand for transfer at this station would soar to 91,000. It is difficult to accommodate the present 35,000 transfers per day at this station.

The routing of the Riverside Line over B & A tracks between Fenway Park and Back Bay Station would remove it from the center of activity through which it now passes. However, this limitation on the effective-

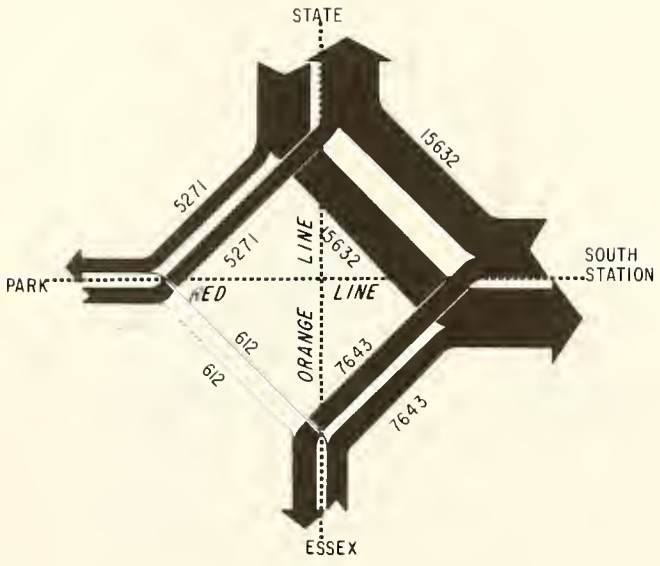


Figure 4-11

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM I
Washington Station

ness of the route should be balanced against improved service to the developing Park Square area and the excellent transfer potential at Back Bay Station that would exist if the Orange Line were relocated as planned.

The availability of B & A right of way for transit use is the unknown that would determine whether System I could be implemented. Information on this subject is inconclusive, although the Authority has discussed it with the Penn Central Transportation Company and the Massachusetts Turnpike Authority.

Joint use of the B & A right of way by transit and railroad equipment has been suggested and studied. Such joint operation does not appear feasible at this time. Factors that influence this decision are the following:

- Likelihood that transit schedules would be disrupted frequently by railroad movements.
- Incompatibility of signal systems to control transit and railroad operations.
- Conflicting regulations of the various labor unions and railway brotherhoods involved.
- Clearance problems caused by power distribution and signal structures as well as by station platforms.

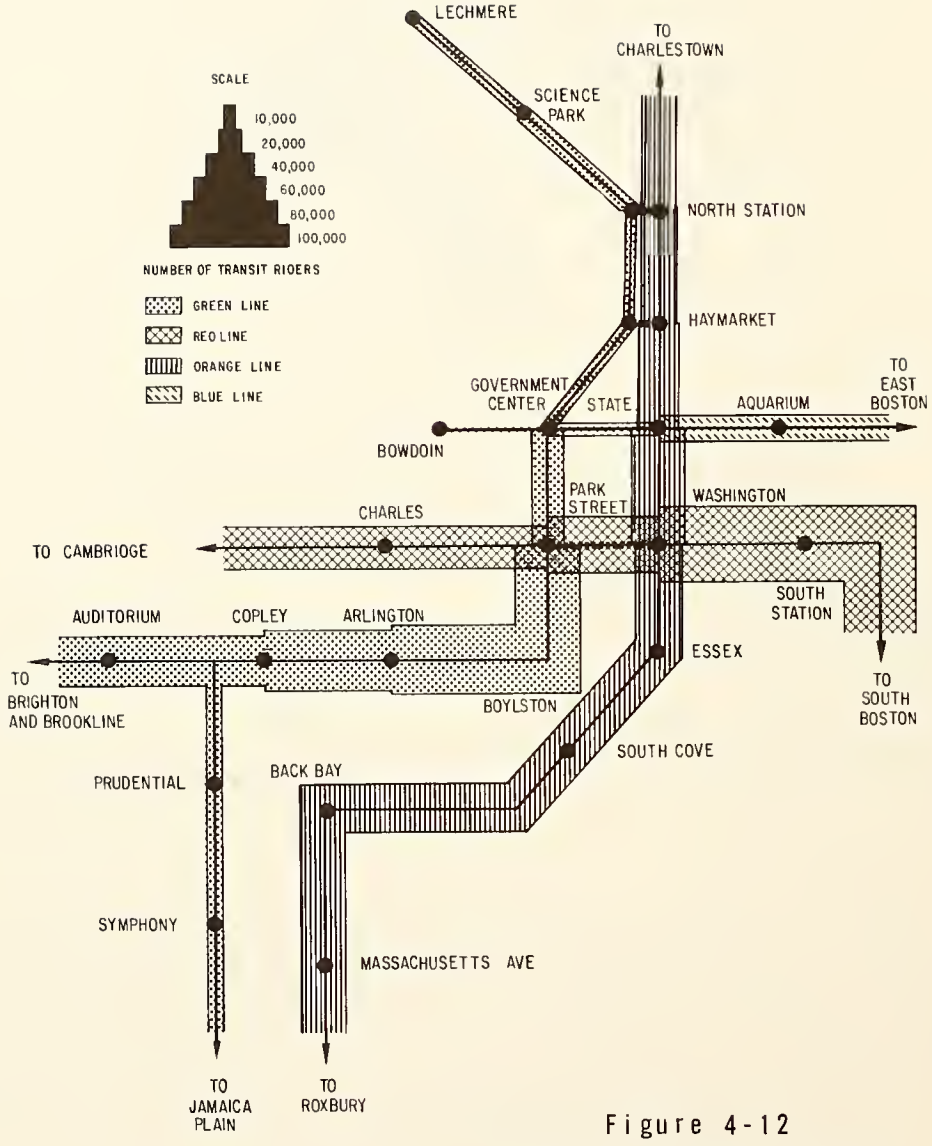


Figure 4-12

ESTIMATED ONE-WAY DAILY TRANSIT RIDERS IN 1990
Existing System with Stage 1 Improvements only

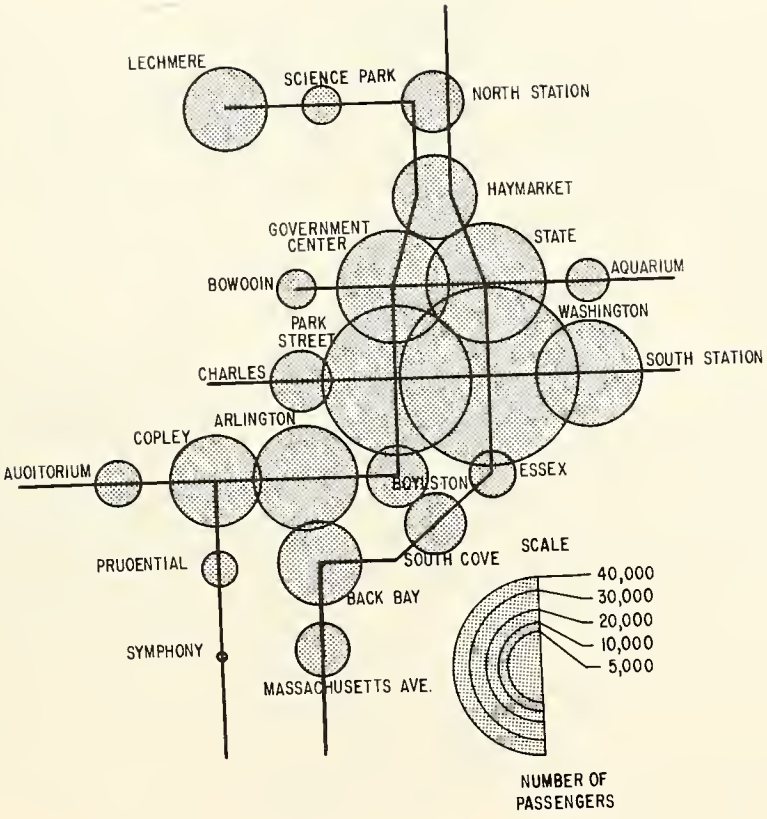


Figure 4-13

ESTIMATED DAILY STATION ENTRIES IN 1990
Existing System with Stage I Improvements only

SYSTEM II

System II is similar to System I previously described in that it would remove the Riverside and the Huntington Avenue Lines from operation in Central Subway. However, while System I would use B&A right of way, System II was developed on the assumption that this property would not be available for transit use.

Construction and operation would be staged over several years. The estimated cost of System II is $198,000,000.

System II is described in the following pages. The plan and profile the ultimate improvement is presented in Volume III of this report.

DESCRIPTION OF ROUTE

General

This system would remove the Riverside and the Huntington Avenue Lines from the Central Subway without requiring acquisition of B&A right of way. In the ultimate stage, the Riverside Line would change its present alignment near Brookline Village to enter a new subway under Huntington Avenue. This subway would connect with the present subway near Northeastern University. Copley Junction would be eliminated for revenue service by breaking out of the old subway just east of Prudential Station and continuing to a new subway transfer station under the Orange Line at Back Bay Station. Tunnels under the Turnpike would link with the new subway under Columbus Avenue. This subway would continue northeastward in tunnel to a new Park Street Station and on to link with the Blue Line at existing Bowdoin Station.

Four stages are envisioned in progressing from the existing system to the one described above.

Stage 1

The route proposed for implementation in Stage 1 is described in Chapter 3.

Stage 2

This stage would consist of rerouting the Huntington Avenue Line to South Station, thereby removing operation of this line from the Central Subway.

The new low-platform cars would continue to operate from a terminal near Brigham Circle in a median reservation in Huntington Avenue and into the existing subway near Northeastern University.

Figure 4-14
SYSTEM II
STAGE 2 PROPOSALS

1. Construct subway from existing Huntington Avenue subway to new Back Bay Station under proposed Orange Line.
2. Build incline to New Haven Railroad right of way.
3. Build stub tunnel headings for future Columbus Avenue Subway.
4. Construct new low-platform transit terminal at South Station.
5. Initiata No. 6 car service from Brigham Circle to South Station.
6. Retain a Connection at Copley Junction for cars going to and from the maintenance facility.

A new subway would be constructed from the north end of Prudential Station, under ramps of the Massachusetts Turnpike, and on to a new subway station under the proposed Orange Line at Back Bay Station. At this point, stub tunnels would be built for the future Columbus Avenue subway extension. Temporarily, however, the Huntington Avenue Line would use an incline to the surface and follow the New Haven tracks to a terminal at South Station.

The routing through Back Bay Station was selected to satisfy the demand for an anticipated 17,000 daily transfers between the Orange and Green Lines at this station.

If Orange Line relocation took place prior to rerouting of Huntington Avenue to South Station, the Green Line would be stub-ended in the new Back Bay subway station. Such combined planning would save the cost of a temporary incline to extend Green Line service from Back Bay Station to South Station. Further study, however, might justify retention of transit service to South Station; possibly even an extension into the financial district to the north.

The existing New Haven right of way between Back Bay Station and the proposed South Cove tunnel is too narrow to accommodate the proposed Orange and Green Lines at the same level.

Stage 3

A new subway would be built under Huntington Avenue between Brookline Village Station and the existing portal near Northeastern University. All existing platforms from Riverside Station through Brookline Village to South Station would be converted to high level platforms.

Other improvements to the Green Line system would include an underground terminal at Canal and Causeway Streets. This would be a bus to rail transfer facility serving both Orange and Green Line subway stations at North Station. The bus terminal would be at ground level. A pedestrian passageway between Boston Garden and the transit station would carry patrons over Causeway Street. Justification for this facility will be determined by a study of the Somerville Corridor now being conducted by others.

The Park Street Station loop would be eliminated. The Beacon Street and Commonwealth Avenue Lines would both terminate at the new North Station. New No. 6 cars used on the Riverside Line in Stage 1 would be shifted to these lines, replacing all PCC cars still in service.

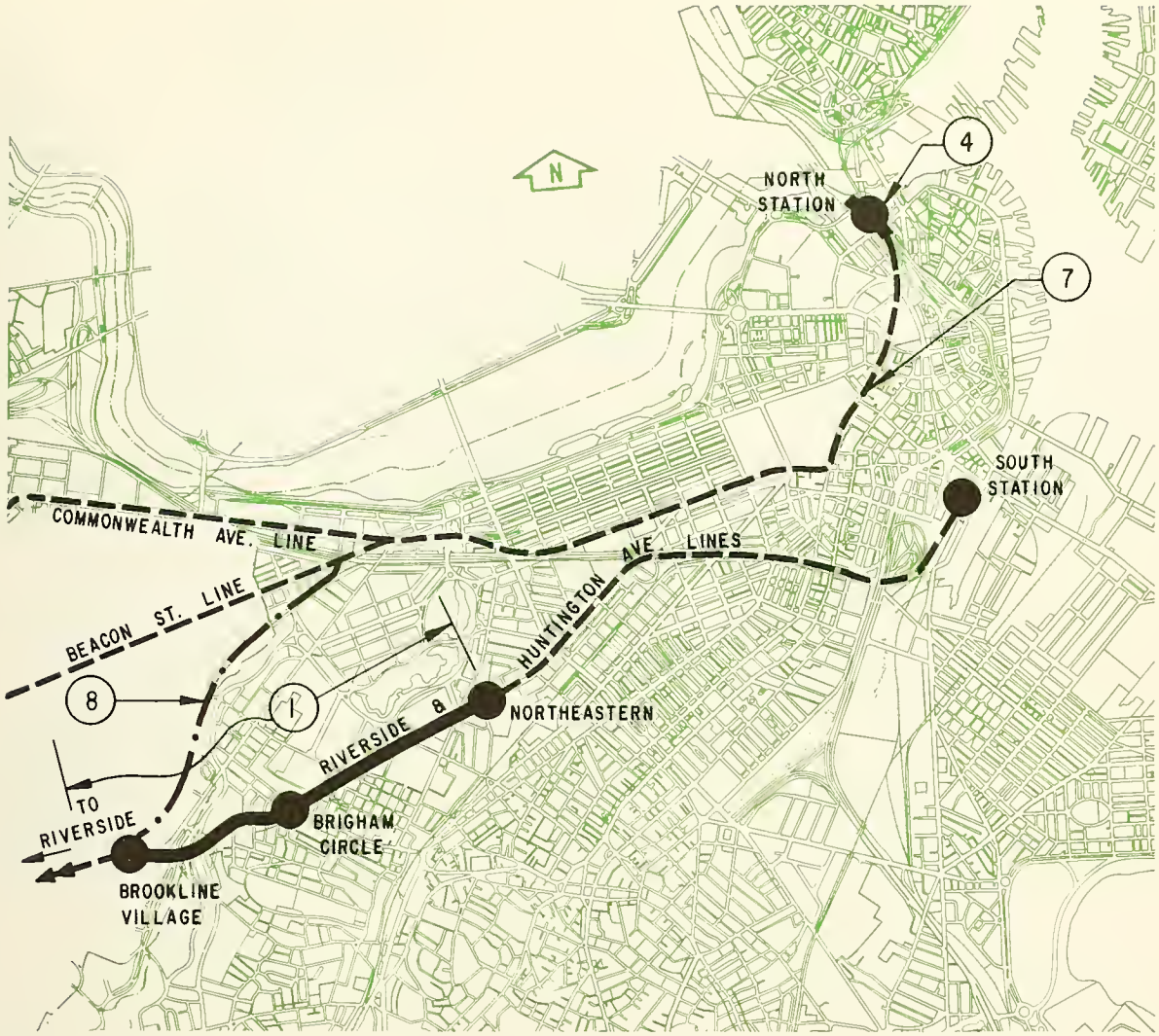


Figure 4-15
SYSTEM II
STAGE 3 PROPOSALS

1. Extend Huntington Avenue Subway from the present portal at Northeastern University to Brookline Village.

2. Build new stations and convert existing station platforms to high level platforms from Riverside to South Station. Build new subway stations at Brookline Village, Brigham Circle and Northeastern.

3. Obtain Blue Line-type rapid transit cars for the Riverside-Huntington operation. Convert shops and build yard at Riverside to service and store these cars.

4. Build North Station subway station and underground car storage facility. Build bus-to-rail transfer facility integrated with Orange and Green Lines at North Station. Remove elevated structure from Causeway Street.

5. Initiate high-platform service, Riverside to South Station.

6. Shift No. 6 cars from Riverside Line to Beacon and Commonwealth Lines, which would terminate at Canal Street.

7. Eliminate loop track at Park Street Station.

8. Determine need for shuttle service, Brookline Village to Kenmore.

Figure 4-16
SYSTEM II
STAGE 4 PROPOSALS

1. Extend new subway from Back Bay Station, under the Massachusetts Turnpike, via Columbus Avenue, Boston Common and Beacon Hill to Bowdoin Station.

2. Begin high-platform rapid transit service from Riverside to Wonderland via Huntington Avenue and Columbus Avenue Subways.

3. Evaluate demand for service to South Station and for an extension from that point northward.

The need for shuttle service between Brookline Village and Kenmore Station should be investigated after the Riverside Line has been re-routed onto Huntington Avenue. Either rail or bus service may be needed to serve the two transit stations at Longwood and Fenway Park which would no longer be served directly.

Stage 4

The long-range objective of linking the Riverside Line with the Blue Line would be achieved in this stage. Subway construction between Back Bay Station and Bowdoin Station would take place along the same route and in the same manner as described in Chapter 4 (System I).

Upon completion of construction and the installation and testing of all equipment, high-platform rapid transit trains would begin operating between Riverside and Wonderland Stations via the Huntington and Columbus Avenue subways.

SYSTEM II

DESCRIPTION OF IMPROVEMENTS

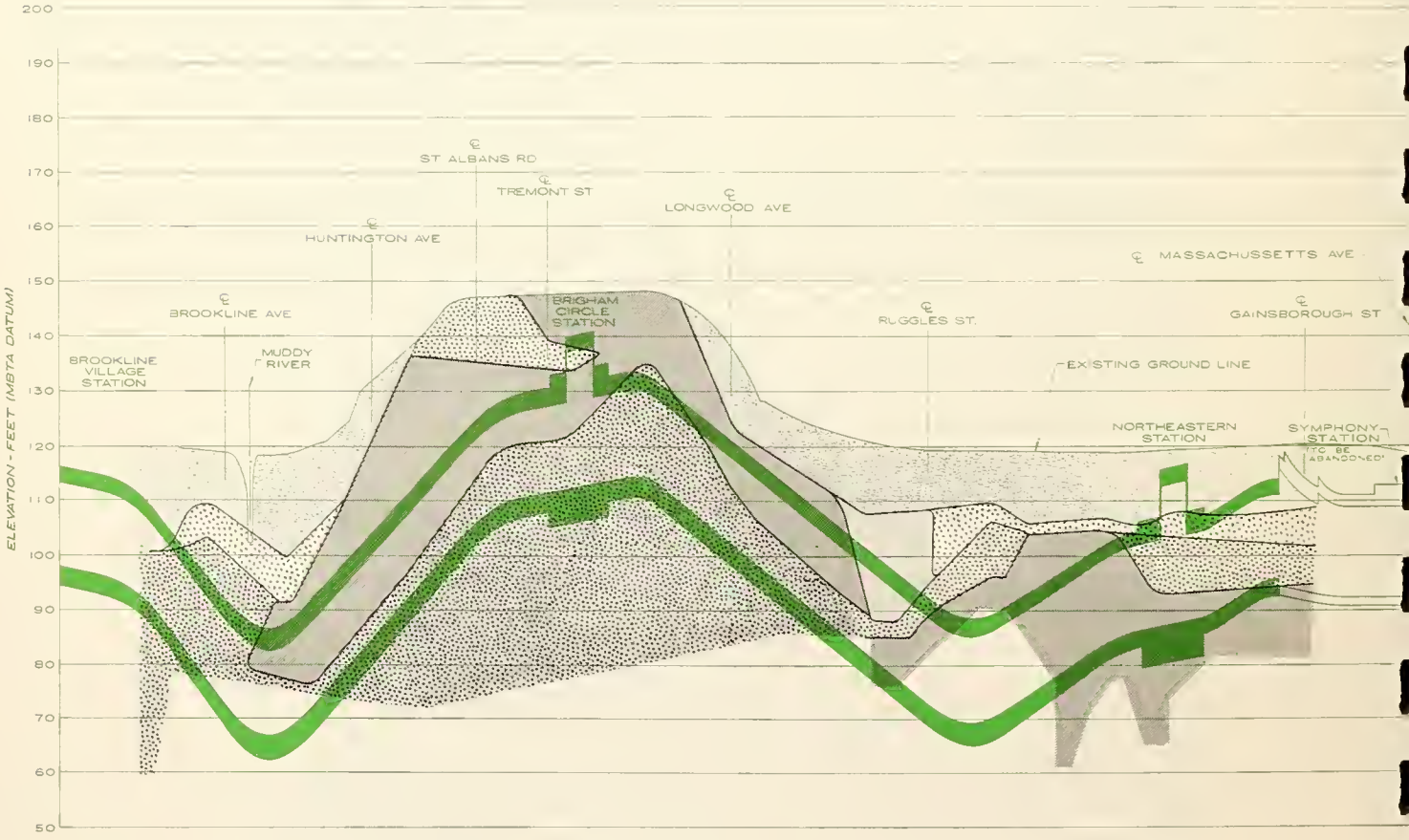
Stage 2

General Construction

Before the Huntington Avenue Line could be removed from the Central Subway, a new subway link would have to be built between existing Prudential Station and the proposed Back Bay Station. Prudential Station platforms would be lengthened 140 feet to the north, and approximately 250 additional lineal feet of existing subway would be modified or replaced to allow the new alignment to curve eastward toward Back Bay Station.

This subway would be constructed by the cut-and-cover method. Timber decking on steel framing in Huntington Avenue would accommodate street traffic. Similarly, ramps from the Turnpike and cross streets would be decked to minimize interference with traffic during installation of the temporary framing.

Soil borings along this route obtained from the Boston Society of Civil Engineers were plotted on the profile of the proposed subway, as shown in Figure 4-17. A layer of water-bearing silt up to 30 feet thick would be encountered in the section parallel to the Turnpike. A layer of silt lies just below the ground water table which is approximately at mean low sea level. Below the silt is a thin layer of sand which settled out of the silt as it was deposited. Below that is a deep layer of soft Boston blue clay, overlain in some areas by a thin,



LEGEND

- SAND AND GRAVEL
- SILT
- FILL
- PEAT
- CLAY
- TILL

SCALE IN FEET

HORIZONTAL 0 400 800 1200

VERTICAL 0 10 20 30

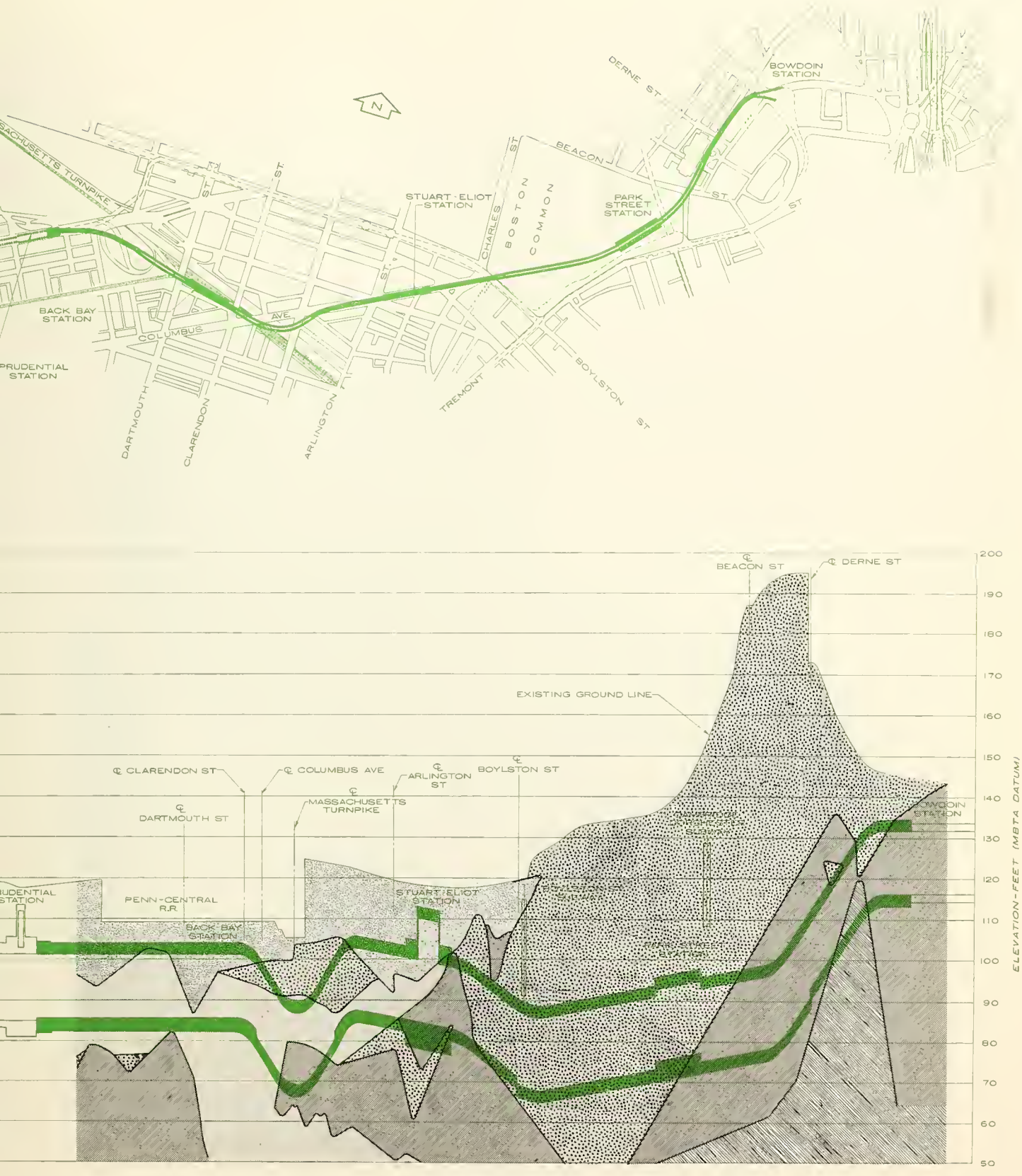


Figure 4-17

SOIL PROFILE ALONG PROPOSED SUBWAY

harder layer of yellow clay. Above the silt and extending to the surface is a layer of fill varying in thickness from 10 to 20 feet, presumably placed when this land was reclaimed from the sea. The extent of filling done in the Back Bay area since colonial days is shown on Figure 4-18.

SOURCE : BOSTON SOCIETY OF CIVIL ENGINEERS

Figure 4-18

EXTENT OF FILLED AREAS IN BOSTON PENINSULA

Proposed subway construction would extend about 20 feet below the ground water table. The silt layer continues another 10 feet below the proposed bottom of excavation. Cutoff walls would penetrate far enough into the clay layer to seal the excavation from percolation of water upward and to preclude heaving of the bottom of the excavation. The cut-off walls would also penetrate deep enough to resist large lateral pressures exerted by the water-bearing silt. These walls might consist of driven interlocking units of sheet steel or precast concrete, or they could be of concrete cast in a slurry-filled trench.

Connection of the new subway to the existing Huntington Avenue subway would require temporary operational modifications to that line through the construction zone. Single-tracking of trains around the area of construction during non-rush hours would permit operation of the Huntington Line to and from the Central Subway during subway construction.

All trackwork installed in new subway would be fastened directly to the concrete invert as shown in Figure 4-5. Existing track would be used on at-grade portions of the New Haven right of way.

The Back Bay transit station would be constructed in subway under the proposed Orange Line, assuming the relocation of this line proceeds as currently planned. The Green Line station would be built by cut-and-cover method. Construction at the east end of the station would include stub tunnel headings under the Turnpike for future extension of the subway.

If the Orange Line has not been relocated through Back Bay Station a temporary incline from subway to the New Haven tracks would be built west of Back Bay Station by framing it into the permanent structure. The Huntington Avenue Line would use this incline and operate over existing New Haven tracks to a terminal at South Station. When Orange Line relocation through Back Bay Station is in operation, the incline would be removed and the Huntington Avenue Line would terminate in the subway station at Back Bay. Passengers would transfer between lines at this station.

New stations to be built at Back Bay and South Station would have low platforms to conform to the new No. 6 cars on the Huntington Avenue Line. The at-grade station alternative at Back Bay would be temporary. On-board fare collection would be used. Station facilities would have canopies over platforms, heated shelters, and stairways to Dartmouth and Clarendon Streets. The subway alternative at Back Bay Station would be integrated with the complete station facilities of the proposed Orange Line.

In this stage a temporary at-grade transit terminal would be built at South Station. A transportation center and commercial complexes currently being planned for this area should consider the possibility of:

- Direct passenger transfer at South Station; and
- Future extension into the financial district.

Traction Power

Traction power would be supplied to the new subway extension between the Huntington Avenue subway and the new Back Bay Station by building a new contact wire system with supplemental feeders. A new catenary system with supplemental feeders would also be built for the new at-grade connection between Back Bay and South Station. The contact wire and catenary systems would permit overhead trolley operation of No. 6 cars. The catenary system would also be suitable for future pantograph operation.

The Huntington Avenue Line route between Brigham Circle and South Station would be fed from existing substations during this stage as follows:

- The section between Brigham Circle and Northeastern Station would be fed as at present from existing feeder Section 25 tied to Coolidge and Newbury Substations.
- The section between Northeastern and Back Bay stations would be fed as at present from existing feeder Section S-10 tied to Newbury Substation. This feeder section, which presently terminates at Copley Junction, would be extended to the new Back Bay Station. The feeders from Newbury Substation to this feeder section would not have to be changed.
- The section between Back Bay Station and South Station would be tied to the present feeder Section S-7 now fed from existing Central and Dewey Substations. Present Section S-7 underground feeders from Central Substation would be tapped at Washington Street and extended to new overhead at that point. Existing Section S-7 feeder from Dewey Substation would be tapped at the substation and extended to new overhead at South Station. Existing feeder Section S-7 would remain in place and continue to feed its present portion of the Riverside, Beacon Street and Commonwealth Avenue lines in this stage.

Power requirements in Stage 2 would be essentially the same as in Stage 1; therefore, the arrangement of new existing substations as

provided in Stage 1 would adequately serve the peak demands of the combined operations of No. 6 cars and PCC cars during this stage.

Signals and Communications

Signal and communication systems as described in Chapter 3 would be installed between Prudential Station and South Station. Interlock protection would be installed at the new junction north of Prudential Station.

Stage 3

General Construction

Eight new transit stations would be built along the Highland Branch between Riverside Station and Brookline Hills Station. The platform would be 3'-3" above top of rail to permit operation of rapid transit cars similar in dimension to those in operation on the Blue Line.

An interior view of a typical station is shown in Figure 4-19. The exterior of the same station appears in Figure 4-20.

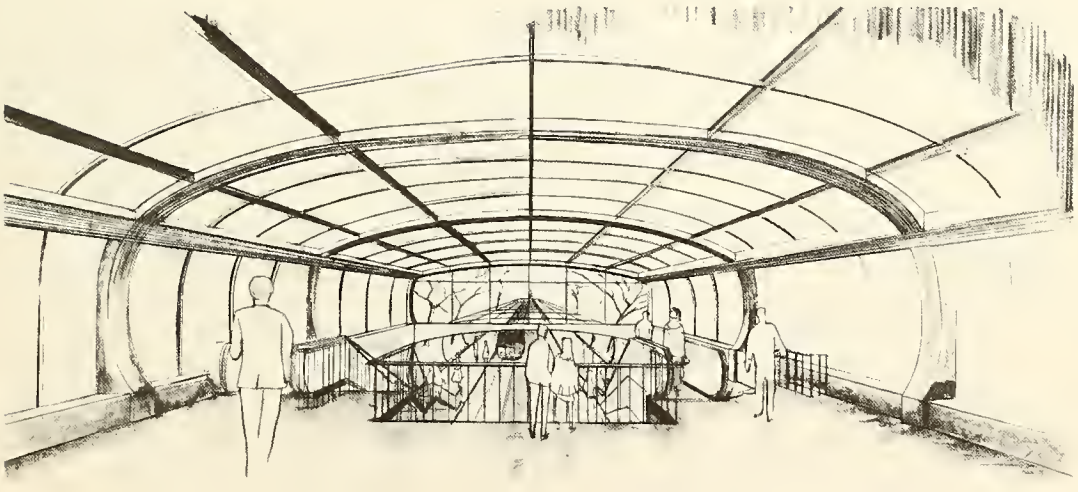


Figure 4-19
INTERIOR VIEW - TRANSIT STATION ABOVE GROUND

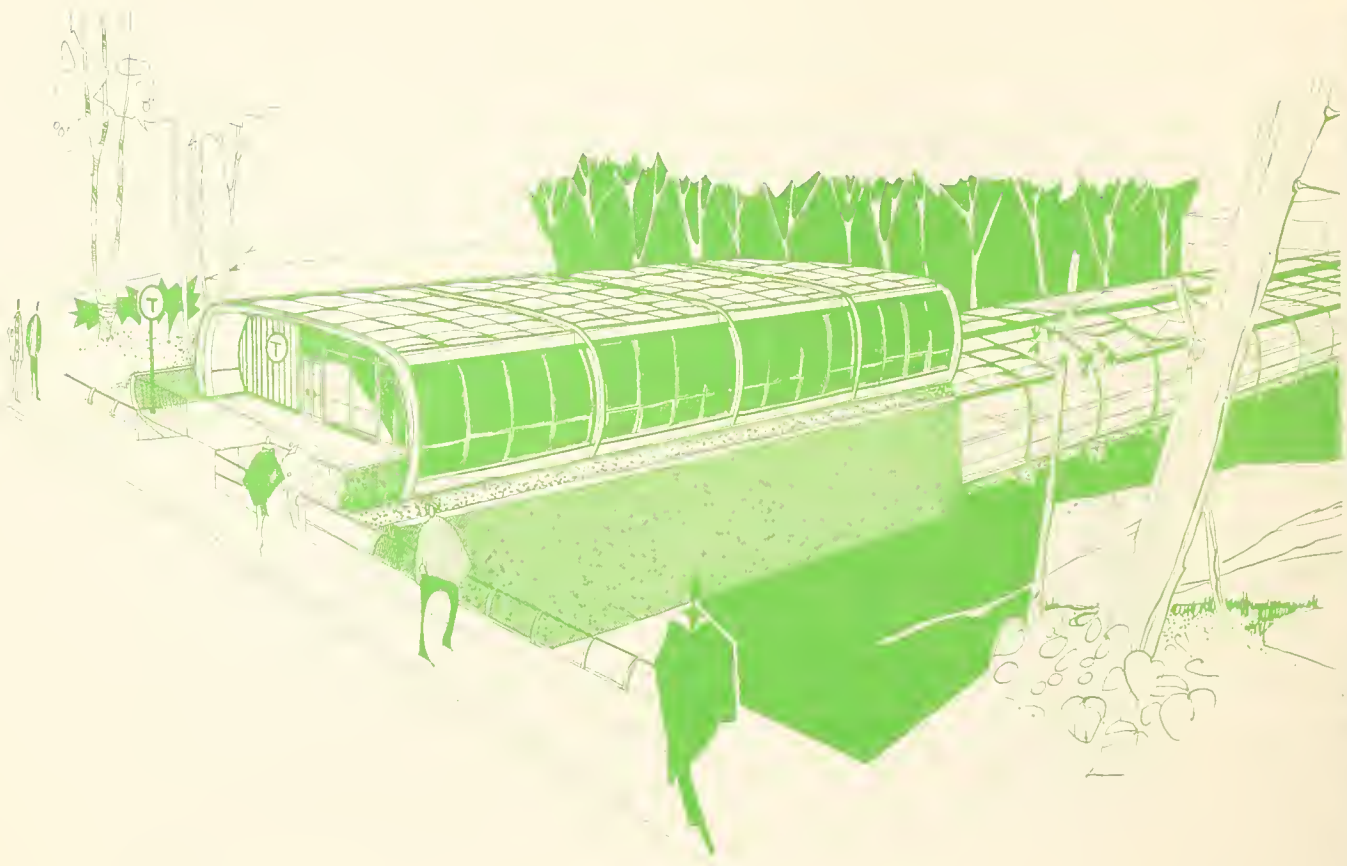


Figure 4-20

EXTERIOR VIEW - TRANSIT STATION ABOVE GROUND

In this stage, major subway construction would take place along Huntington Avenue. No. 6 car operation would be replaced by buses during construction of a new subway between Brookline Village and the existing subway portal near Northeastern University.

The incline from surface into subway would begin about 1,000 feet west of the Washington Street bridge in Brookline. The new Brookline Village Station would have two levels serving Riverside Line high-platform trains at the subway level and low-platform trains at grade directly overhead. The fare collection lobby would be over the tracks, with access from both sides of the track, from Station Street, and from the plaza of the new Hearthstone Building. Details of this station are shown on Exhibit 122, Volume III.

A subway would be constructed under the Muddy River between Brookline Village and Brigham Circle Stations, and would continue under

the median of Huntington Avenue to the existing subway near Northeastern Station. Plans and profile shown in Volume III as well as estimates of cost are based on cut-and-cover construction. Tunneling of this subway was also studied as a means of minimizing interference with traffic or utilities and disturbance of the ecology of the area. The additional cost of tunneling the proposed subway between Brookline Village and Northeastern Stations is estimated to be $25 million. The subway stations at Brookline Village, Brigham Circle and Northeastern University would be built by the cut-and-cover method in either case, as would the incline west of Brookline Village.

Subway stations at Brigham Circle and Northeastern University would have center platforms with underground fare collection mezzanines over the tracks. Access would be from street level along both sides of Huntington Avenue. Free passage from one side of the street to the other is proposed. Maximum surveillance of both levels of the station would be assured by offering the agent good visibility from the mezzanine level.

Decking of the excavation at Brookline Village Station would permit transit operations to continue on the Riverside Line during construction. Partial decking over the Huntington Avenue stations would facilitate movement of street traffic during construction.

Operation of No. 6 cars in the median of Huntington Avenue would be suspended during subway construction. These cars would be replaced by buses which would operate with other motor vehicles over the partially decked subway excavation. Partial decking would allow street traffic to operate at near-normal capacity. It would also afford the contractors ready access to the excavation from street level, resulting in faster construction progress.

Several major structures cross the route of the proposed subway. The Muddy River conduits may require underpinning. The proposed I-695 Inner Belt highway would cross over the subway profile. The timing of the two projects would determine whether both sections or the subway alone would be built in cut-and-cover in the area of the crossing.

Each of the two Stony Brook conduits is a double-barrelled concrete and brick structure carrying storm flow into the Fens. The proposed subway profile would require that a siphon be constructed to carry the 900 cfs. peak flow of the easterly conduit. This conduit would be dammed upstream or diverted during construction of the siphon. The other conduit, with a capacity of 2700 cfs., would not be affected by subway profile. However, the conduit would be underpinned or reconstructed, as necessary, where the subway passed under it.

With the exception of the Brigham Circle Station, construction activity along the Huntington Avenue subway would be largely in water-bearing sands and gravels, lying below the ground water table. The elevations of adjacent buildings should be monitored during construction to detect any settlement. Although pumping might be necessary to permit construction, care should be exercised to preclude subsidence of nearby structures. Ground water recharge might be necessary to prevent excessive drawdown. Consideration should be given to using concrete cut-off walls to minimize such problems.

All existing station platforms from Riverside to South Station would be raised to 3'-3" above top of rail. This would permit a change from No. 6 cars to high-platform cars similar to these used on the Blue Line.

Construction in the North Station area and elimination of the Park Street loop is described under Stage 3 of System I.

Traction Power

It is proposed that the new Riverside high-level rapid transit cars operate with pantograph collectors from the overhead catenary system between Riverside and Back Bay Stations.

New substations, in addition to those installed in Stage 1, would be built at Brookline Village and at Ruggles Street to provide additional power and to keep voltage within specified limits for the new high-level rapid transit cars on the Riverside Line between Riverside and Symphony Stations. The present Cooks Junction Substation with two-100 kw mercury arc rectifiers fed from 25-cycle AC power from MBTA generating stations would be rehabilitated and increased in capacity. New solid state, silicon-diode rectifier units and associated rectifier transformers and gear would be installed and the substation fed from a new 60-cycle AC power source. The changeover of Cooks Junction Substation would be made while low-level cars were still in operation and peak demands on the station could be met by one existing rectifier unit.

The section of the Riverside Line between Symphony Station and South Station would be fed from the new Back Bay Substation proposed for the new Orange Line extension and the new Dewey Substation proposed for the Orange and Red Lines. One rectifier unit and associated equipment would be required in the Back Bay Substation in addition to the two-3000 kw units proposed for the Orange Line. It is assumed that during this stage neither the Orange, Red nor Riverside Lines would be operating under ultimate headways and that the capacity of the new Dewey Substation as proposed for the Orange and Red Lines would be

adequate to handle the additional load of the Riverside operation to South Station.

The Commonwealth Avenue and Beacon Street Lines would continue to operate over their present routes except that they would both be terminated at Canal Street. The new No. 6 cars used on the Riverside Line during Stages 1 and 2 would be put into service on these lines. The present Huntington Avenue Line service would be replaced by the new Riverside operation between Brookline Village and South Station.

With all power loads of the Riverside and Huntington Avenue Lines removed from existing Coolidge, Oak Square, Newbury, Central, Dewey and North Station Substations, sufficient capacity would be available to meet peak demands on the Commonwealth Avenue and Beacon Street Lines which would be increased by the transfer of the new No. 6 cars to these lines from the Riverside Line.

Existing direct suspension overhead contact wire distribution systems for the surface operations of these two lines would be rehabilitated by installing new contact wire throughout and replacing support poles, pole brackets and span wires as necessary for smooth operation. Feeder capacities in some sections of these lines would have to be increased to maintain voltage levels within prescribed limits.

Stage 4

General Construction

Subway construction between Back Bay Station and Bowdoin Station has been described in System I.

Traction Power

The power distribution and current collection system for the proposed Riverside-to-Wonderland route via the Huntington and Columbus Avenue Subways would be as follows:

- Riverside to Back Bay--Pantograph operation from an overhead catenary system as in Stage 3;
- Back Bay to Bowdoin--collector shoe operation from a third rail system installed in this stage;
- Bowdoin to Maverick--collector shoe operation from an existing third rail system; and
- Maverick to Wonderland--pantograph operation from the existing overhead catenary system.

Changeover from overhead to third rail current collectors would be made during station stops at Back Bay and Maverick.

Power and voltage regulation requirements for the sections between Riverside and Symphony Station would be the same as in Stage 3. Therefore, no changes or additions would be necessary for ultimate operation under Stage 4.

The section of the new route between Symphony and Stuart-Eliot Stations would be fed from the new Back Bay Substation proposed for the new Orange Line extension. The capacity of the Back Bay Substation, including the rectifier unit and associated equipment added for the Riverside operations in Stage 3, would be adequate to handle the additional power requirements for the ultimate Riverside-Wonderland operations over this section of the route.

The section between Stuart-Eliot and Bowdoin Stations would be fed from the new Dewey Substation proposed for the new Orange and Red Line systems. Two rectifier units and associated equipment would be required in the new Dewey Substation in addition to the two-3000 kw units proposed for the Orange Line and two-3000 kw units proposed for the Red Line. One set of feeders would be installed from the new Dewey Substation to serve this section. This set would run from the substation to Park Street Station via the Red Line Subway.

A new third rail power distribution system would be installed in the subway connection between Back Bay and Bowdoin Stations.

Train operations and power and voltage regulation requirements for the Commonwealth Avenue and Beacon Street Lines would be the same as in Stage 3. No changes or additions would be necessary, therefore, to serve ultimate operations under this stage.

ANTICIPATED BENEFITS AND LIMITATIONS

The benefits to be derived from System II would be generally similar to those described earlier under System I. System II would exhibit slightly greater savings in travel time.

The appeal of System II would be enhanced by the high level of service rendered to the educational and medical institutions along Huntington Avenue. Prudential Station would receive excellent service, whereas it would be poorly patronized in other systems. Even more patrons would use this station if the Orange Line were not relocated to the New Haven right of way as was assumed in all systems studied.

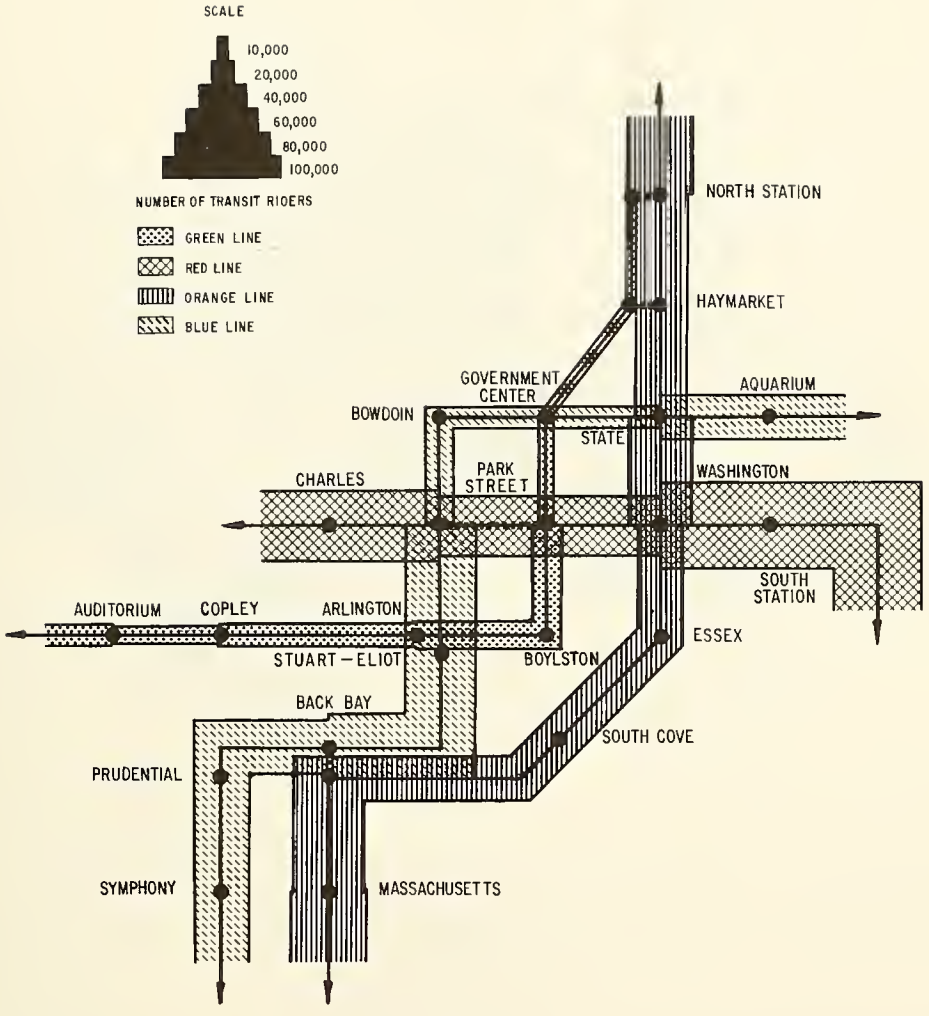


Figure 4-21

ESTIMATED ONE-WAY DAILY TRANSIT RIDERS IN 1990
SYSTEM II

Another major benefit would be that the B & A could continue in operation if System II were implemented. Although the cost would be an estimated $60,000,000 greater than for System I, this differential would presumably be considerably less if the cost of right of way were included.

Figure 4-21 shows the average daily one-way passenger volumes that would use the transit lines of System II in 1990.

Daily station entries for System II are illustrated graphically in Figure 4-22.

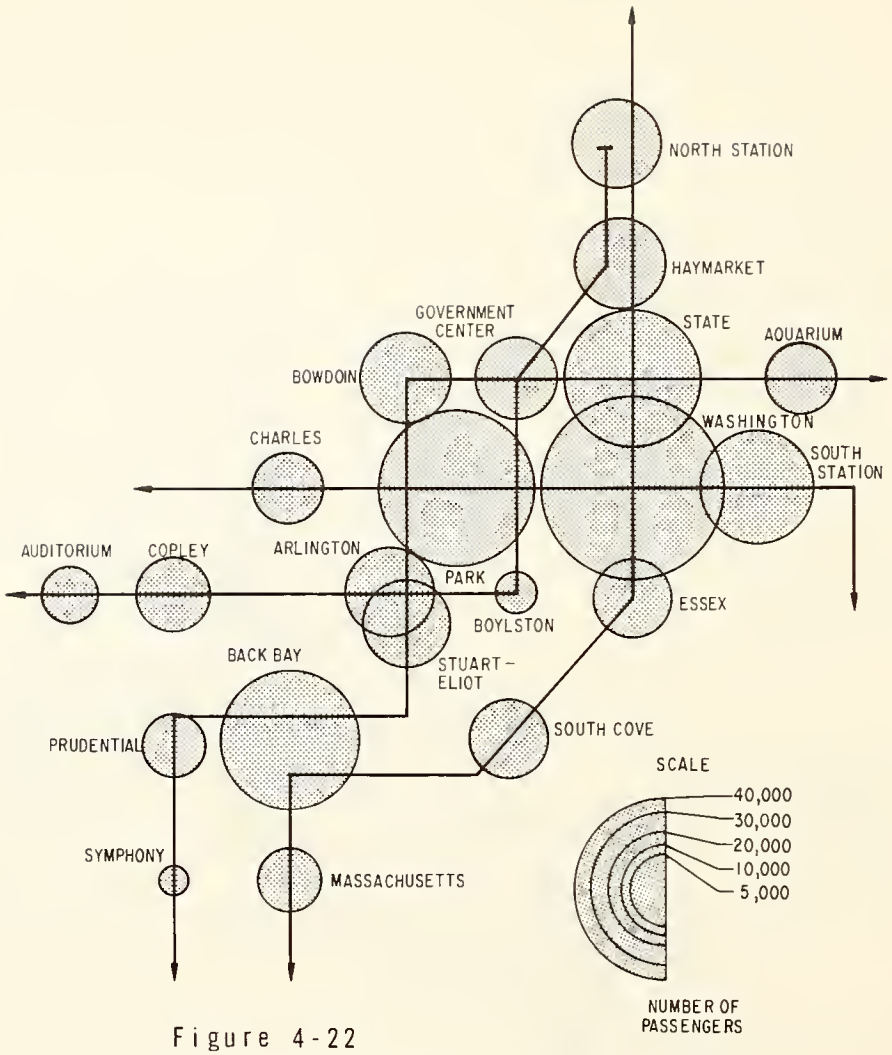


Figure 4-22

ESTIMATED DAILY STATION ENTRIES IN 1990
System II

The importance of the new Park Street Station as a transfer point between lines would be even more apparent in System II than in System I, as may be seen in Figure 4-23.

The major transfer movements would be between the connected Blue-Green Line and the Red Line.

A total of 112,000 daily transfer movements would take place in the Park Street Stations.

The transfer movements at Back Bay Station are shown in Figure 4-24.

The transfer between lines at this station would be facilitated by locating the Orange Line directly over the Blue-Green Line as shown on Exhibit 126 in Volume III. The 47,000 daily transfers expected at Back Bay Station would make this one of the key transfer points on the system.

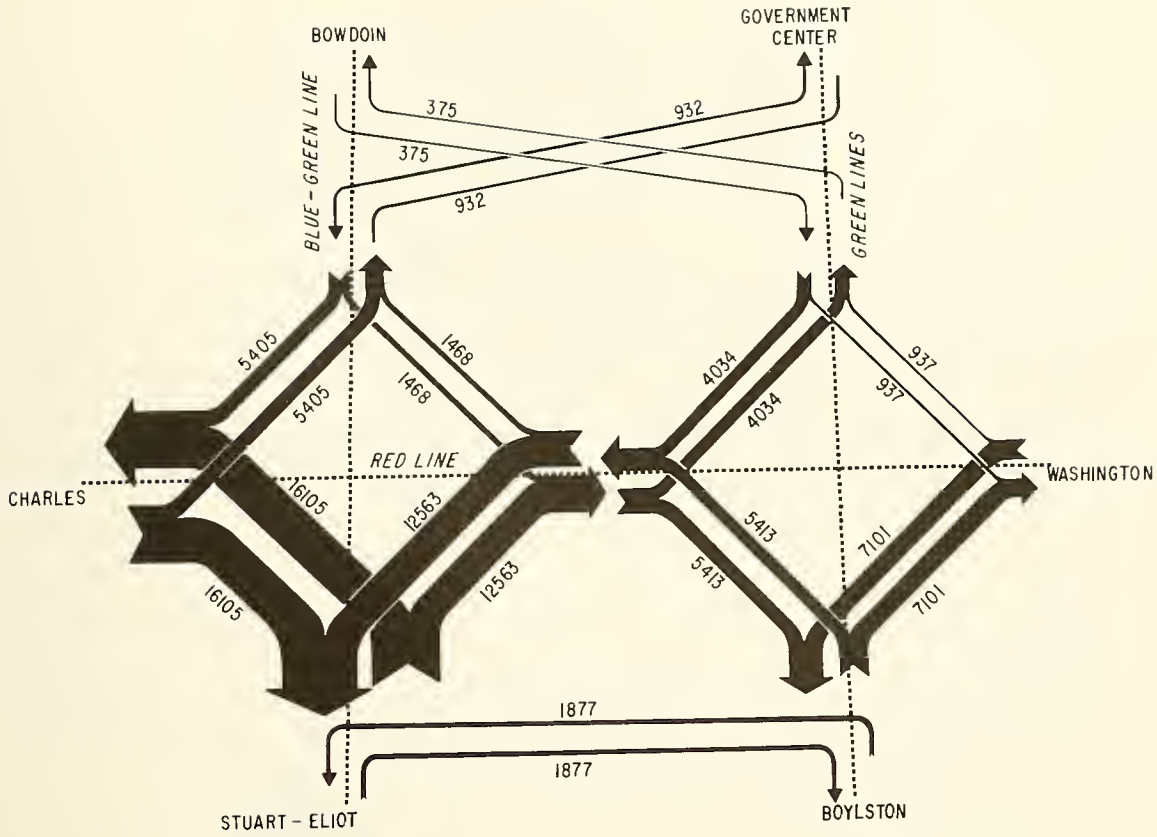


Figure 4-23

ESTIMATED DAILY
TRANSFERS IN 1990 - SYSTEM II
Park Street Station

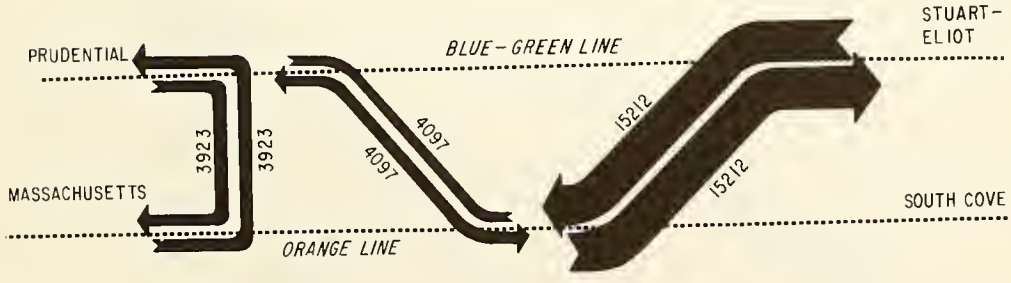


Figure 4-24

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM II
Back Bay Station

The importance of Government Center Station as a transfer point would be diminished by connecting the Blue and Green Lines between Park and Bowdoin Stations.

About 3,000 daily transfers would take place here in 1990, rather than the 22,000 that would occur if the connection were not built. See Figure 4-10.

Transfers at North Station are shown in Figure 4-26.

The Green Lines would terminate at this station. Nearly 13,000 daily transfers would occur here in 1990 between the Green Lines and the Orange Line.

The transferring of 58,500 passengers per day at Washington Station is illustrated in Figure 4-27.

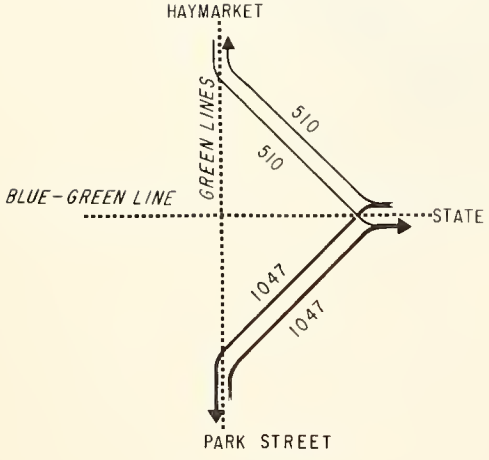


Figure 4-25

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM II
Government Center Station

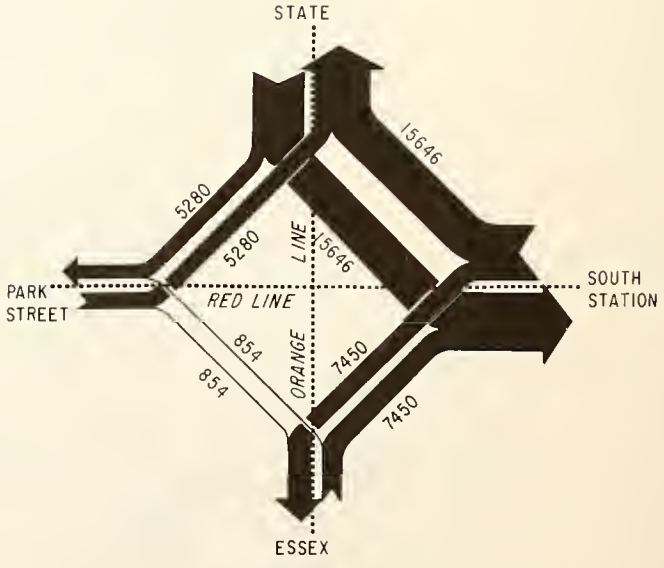


Figure 4-27

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM II
Washington Station

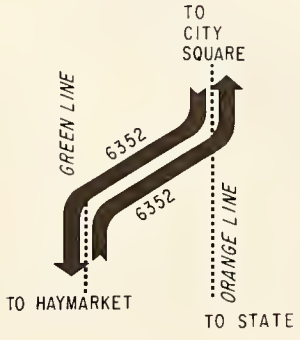


Figure 4-26

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM II
North Station

SYSTEM III

The essential difference between System III and previously described Systems I and II is that it would convert the existing Boylston Street Subway to high-platform rapid transit operation for the exclusive use of the Riverside Line.

This system would be built in four stages at a presently estimated cost of $180,000,000.

Stage 1 improvements are described in Chapter 3.

Volume III of this report contains plans of the ultimate improvements proposed in this System.

DESCRIPTION OF ROUTES

General

In its ultimate development, System III would consist of four separate routes:

1. The Riverside-Blue Line from Riverside to Wonderland.

2. The Huntington Avenue Line from Brookline Village to North Station.

3. The Commonwealth Avenue Line from Boston College to Kenmore Station.

4. The Beacon Street Line from Cleveland Circle to Beacon Transfer Station.

The Riverside Line would continue to operate from the Riverside terminal over the existing Highland Branch and into the Boylston Street subway via Beacon junction. East of Arlington Station this line would enter new subway under Boston Common to a new Park Street Station. The new subway from this point to its junction with the Blue Line subway at Bowdoin Station would be identical with the subway described in Systems I and II.

The Huntington Avenue Line would begin at Brookline Village Station and continue in subway to Brigham Circle Station where it would emerge from below ground. Continuing in the median of Huntington Avenue to Northeastern University, it would enter the existing subway at that point. A new incline north of existing Prudential Station would route the line

through Back Bay Station. New tunnels under the Massachusetts Turnpike would connect with the presently abandoned Tremont Street Subway. The route would continue through the modernized Boylston, Park Street, Government Center and Haymarket Stations to a new underground terminal at North Station.

The Beacon Street and Commonwealth Avenue Lines would continue to operate in the medians of these streets to the proposed turnback and passenger transfer facilities at Beacon Transfer and Kenmore Stations.

Stage 2

The Riverside Line would continue to operate over its present route between Riverside and Lechmere using the new No. 6 cars placed in service in Stage 1.

The Huntington Avenue Line would be removed from the Central Subway and rerouted via a new incline from existing subway at Prudential Station to a new Back Bay Station on the B&A. If the proposed relocation of the Orange Line had been completed and it was in operation between the Central Area and Back Bay, the Huntington Avenue Line would be terminated at Back Bay. If the relocation had not taken place, the line would be extended to South Station.

Plans in Volume III for rerouting the Huntington Avenue Line between Back Bay and South Station were based on the entire B&A right of way being available for use of MBTA. If single-track railroad service had to be retained in this corridor, the relocated Orange Line alignment between the South Cove tunnel and Back Bay Station might be reduced to two tracks as one alternative to be considered.

The Commonwealth Avenue Line would continue to operate through the Central Subway.

Beacon Street Line passengers would be transferred to the Riverside Line at Beacon Transfer Station which would be constructed near Maitland Street in Stage 2.

Stage 3

In this stage the Riverside Line would be converted to high-platform rapid transit operation using cars similar to those now running on the Blue Line. The alignment would follow new subway tunnels built in this stage under Boston Common and Beacon Hill between Arlington Station on the Green Line and Bowdoin Station on the Blue Line. The alignment of a new subway between Park Street and Bowdoin Stations was described under Stage 4 of System I. This newly-created route through the Central Area would link the Riverside Line with the Blue Line for rapid transit operation between Riverside and Wonderland Stations.

Figure 4-28
SYSTEM III
STAGE 2 PROPOSALS

1. Build a connection north of Prudential Station from Huntington Avenue Subway to the A & B tracks.

2. Build low-platform stations at Back Bay and South Station.

3. Begin low-platform service on Huntington Avenue between Brigham Circle and South Station.

Figure 4-29
SYSTEM III
STAGE 3 PROPOSALS

1. Build a new subway under Boston Common and Beacon Hill joining Boylston Street Subway near Arlington Station with Blue Line Subway at Bowdoin Station.

2. Build naw tunnels under the Massachusatts Turnpike to connect existing Tremont Street Subway with B &A tracks east of Back Bay Station.

3. Convart shops and build a yard for high-platform rapid transit cars at Riverside. Obtain a fleet of Blue Line-type rapid transit cars for Riverside Line operations.

4. Build Beacon Transfer and Fenway Transfer Stations in subway.

5. Convert all Riverside Line stations, and Kenmore, Auditorium, Copley and Arlington Stations to high platforms.

6. Initiate high-platform service between Riverside and Wonderland via Boylston Street and Boston Common Subways, transferring passengers from the Beacon Street and Commonwealth Avenue Lines to the Riverside Line.

7. Build the North Station subway station and an underground low-platform car storage facility. Build a bus-to-rail transfer facility integrated with the Orange and Green Lines at North Station. Remove the Causeway Street elevated structure.

8. Shift No. 6 cars from Riverside Lina to Beacon Street and Commonwealth Avenue Lines.

9. Remove the loop track from Park Street Station.

10. Modernize the Park Street and Boylston Stations.

Figure 4-30
SYSTEM III
STAGE 4 PROPOSALS

1. Build a subway for No. 6 cars from Brigham Circle to Brookline Village Station. Retain Arlington-Boylston Station trackage to permit Huntington cars to reach the riverside shop for maintenance.

2. Build Brigham Circle and Brookline Village Stations in subway and provide for passengers to transfer between lines at Brookline Village Station.

3. Initiate low-platform service from Brookline Village to North Station via Huntington Avenue, Back Bay Station and the Tremont Street tunnels.

4. Evaluate demand for service to South Station and the need for an extension from that point northward.

The Huntington Avenue Line would be diverted from its temporary terminal at South Station into newly-built tunnels under the Massachusetts Turnpike. These would connect the B&A tracks with the presently-unused portion of the Tremont Street Subway. A previous study by others established that the existing subway would adequately accommodate such a routing. However, construction of portions of the Tufts Medical Center subsequent to that study necessitated modification of the previously recommended alignment. The rerouted Huntington Avenue Line would extend from Brigham Circle to a reconstructed North Station subway terminal, through the existing Tremont Street Subway, and past the newly-modernized Boylston and Park Street Stations.

The present passenger service between North Station and Lechmere Terminal would be discontinued.

The Beacon Street Line would end in a new stub-end station under Beacon Street between Park Drive and the Massachusetts Turnpike. Passengers would transfer from this line to a companion station on the Riverside Line near Maitland Street.

The Commonwealth Avenue Line would be terminated at the existing Kenmore Station. A transit rider bound for the Central Area would transfer across the platform to the through-routed Riverside Line.

Stage 4

The only route change in this stage would be the extension of the Huntington Avenue Line in subway from Brigham Circle to Brookline Village. This improvement would permit passengers to transfer at Brookline Village from the Riverside Line to the Huntington Avenue Line.

Passenger service could still be provided from the Huntington Avenue Line to South Station over the remaining single track bypassing the Tremont Street and South Cove inclines. The demand for this service would be evaluated.

DESCRIPTION OF IMPROVEMENTS

Stage 1

Improvements proposed for implementation in Stage 1 are described in Chapter 3.

Stage 2

Track and Roadbed

With the exception of tracks required in the new subway connection north of Prudential Station, the trackage needed during this stage al-

ready exists. Crossovers would be added west of South Station to allow Huntington Avenue Line trains to switch at this terminal station.

General Construction

The only major structures required to implement the removal of the Huntington Avenue Line from the Central Subway would be a new junction with the existing subway north of Prudential Station and an incline to the B&A tracks west of Dartmouth Street. These connections would be built by the cut-and-cover method, with temporary decking over Huntington Avenue and the Turnpike ramp to accommodate street traffic during construction.

Stations

Two new stations with low platforms would be built at Back Bay and South Station.

Access to Back Bay Station would be through station lobbies at Dartmouth and Clarendon Streets as proposed for the Southwest Extension Project on the Orange Line.

South Station facilities would be developed in conjunction with renewal plans being prepared by others.

Passenger transfer facilities would be included in both stations. At Back Bay Station, Huntington Avenue riders could transfer to the Orange Line while transfer to the Red Line would be possible at South Station.

Traction Power

A new contact wire system with supplemental feeders would be provided for the new connection between the existing Huntington Avenue subway and the new Back Bay Station. A new catenary system with supplemental feeders would also be built for the new at-grade connection between Back Bay and South Station. The contact wire and catenary system would be suitable for the trolley pole operation of both present and proposed new No. 6 cars. The catenary system would also be suitable for possible future pantograph operation.

The new Huntington Avenue route between Brigham Circle and South Station would be fed from existing substations during this stage as follows:

- The section between Brigham Circle and Northeastern Station would be fed as at present from existing Feeder Section 25 tied to Coolidge and Newbury Substations.

- The section between Northeastern and Back Bay Stations would be fed as at present from existing Feeder Section S-10 tied to Newbury Substation. This feeder section, which presently terminates at Copley Junction, would be modified to extend to the new Back Bay Station. No change in the feeders from Newbury Substation to the feeder section would be required.

- The section between Back Bay Station and South Station would be tied to the present Feeder Section S-7 now fed from existing Central and Dewey Substations. Present Section S-7 underground feeders from Central Substation would be tapped at Washington Street and extended to new overhead at that point. Existing Section S-7 feeder from Dewey Substation would be tapped at the substation and extended to new overhead at South Station. Present Feeder Section S-7 would remain in place and continue to feed its portion of the Riverside Line operating through the Central Subway during this stage.

Stage 2 power loads on Woodland, Cooks Junction, Hammond Pond, Reservoir and Oak Square Substations would remain the same as in Stage 1. Due to the branch operations from the Central Subway and the rerouting of the Huntington Avenue Line to South Station, Stage 2 power loads on Newbury, Central, Dewey and North Station Substations would be less than in Stage 1. Therefore, the arrangement of new and existing substations as provided in Stage 1 would adequately serve the peak hour power demands of the revised operations during this stage.

Signals and Communications

The signal and communication systems described in Stage 1 would be extended in this stage to the rerouted portion of the Huntington Avenue Line between Prudential Station and South Station.

Rolling Stock and Operations

The No. 6 cars purchased and placed in service on the Huntington Avenue Line in Stage 1 would be diverted from the Central Subway to South Station via B&A right of way east of Huntington Avenue.

Vehicle Support Facilities

Maintenance, repair and storage facilities for PCC and No. 6 cars described in Stage 1 would be used during this stage.

The track connection between the Huntington Avenue Line and the Central Subway at Copley Junction would permit movement of these cars to the Riverside Shops for major maintenance and repair.

If the track connection between the relocated Orange Line and the proposed Dover Street yard had been built, a new track connection between the Orange Line and the Huntington Avenue Line east of Back Bay Station would permit cars on the Huntington Avenue Line to be taken to the Dover Street Shops for maintenance and minor repairs.

Stage 3

Track and Roadbed

A new yard would be built near the Riverside Terminal to store the new rapid transit cars that would begin operating on the Riverside Line. A description of this yard and track realignment work to be performed on the Highland Branch in this stage is described in Stage 3 of System I.

Underground storage tracks for new No. 6 cars would be built in the North Station area. These tracks would be used by the double-end No. 6 cars that would be transferred from the Riverside Line to the Beacon Street and Commonwealth Avenue Lines later in this stage. See Exhibit 61 in Volume III of this report for details of this storage facility.

The loop track and both outer tracks at Park Street Station would be removed. Huntington Avenue Line trains that now use the loop would then operate on the realigned center tracks through Park Street Station and turn back via the Government Center Loop or at the new North Station terminal.

All trackwork installed in the new subways under Boston Common and under the Massachusetts Turnpike would be fastened directly to the concrete invert as shown on Figure 4-5.

General Construction

The following major structure would be built in this stage to permit rerouting of the Riverside and the Huntington Avenue Lines:

- The Beacon Transfer Terminal Station for the Beacon Street Line at Maitland Street.
- The Fenway Transfer Station on the Riverside Line at Maitland Street.
- Tunnels under the Massachusetts Turnpike at Tremont Street for the Huntington Avenue Line.

- A subway under Boston Common and Beacon Hill between Arlington and Bowdoin Stations.

A new subway terminal station would be built under Beacon Street immediately west of the Massachusetts Turnpike. Beacon Street Line patrons would use this station to transfer to the Riverside Line, where a companion Fenway Transfer Station would be built in subway. This new station on the Riverside Line would replace existing Fenway Park Station which is now at grade under the Park Drive bridge. Construction of these two stations would be staged to minimize interference with transit operations. Buses between Longwood and Kenmore stations might be required during certain phases of construction to carry Riverside Line patrons around the construction site.

Twin tunnels under the Massachusetts Turnpike at the Arlington and Tremont Street bridges would be built to carry trains of the Huntington Avenue Line from the B&A tracks to the abandoned subway under Tremont Street. Each of these circular tunnels would be about 600 feet long, with at least five feet of earth between them laterally to prevent the driving of the second tunnel from exerting excessive pressure on the first tunnel. An important feature of the construction of these tunnels would be the tunnelling in soft soil under air pressure because the track profile would be 30 feet below the ground water table at one point. In addition to underpinning or bracing a three-foot thick Turnpike slab designed to resist uplift forces, it would be necessary to keep the 54-inch main drain of the Turnpike in operation.

The incline into these tunnels from the B&A tracks south of the Turnpike would be built in open cut. North of the Turnpike, about 1,300 feet of double-box subway would be built by the cut-and-cover method to join with the existing Tremont Street tunnels near Stuart Street.

Extensive underpinning or reconstruction of the Arlington and Tremont Street bridges over the Turnpike might be necessary in connection with subway construction on the proposed alignment.

The subway under Boston Common and Beacon Hill between Arlington Station and Bowdoin Station would be built in a manner similar to that described in Stage 3 of System I between Park Street and Bowdoin Stations. A connection would be built to the Boylston Street Subway east of Arlington Station, however, instead of tunnelling under the existing Subway as in System I. A track connection would be maintained in subway from the new subway to the remaining portion of the Boylston Street subway leading eastward into the Tremont Street Subway. This connection would keep a rail route open between the Tremont Street Subway--where No. 6 cars would be in use--and the Riverside Shops where cars of this type would be maintained.

Stations

New stations with high platforms would be built between Riverside and Longwood Stations. Exhibits 112 through 116 in Volume III of this report illustrate several of the proposed stations.

Fenway Transfer Station with a high center platform would be constructed in this stage.

Existing stations along the Boylston Street Subway between Kenmore and Arlington Stations would be converted from low to high platforms. Stairways and escalators would be modified to accommodate the raising of platforms to 3'-3" above top of rail.

Park Street Station would be built with high platforms in this stage and integrated with a modernized station on the Green Line and a modified station on the Red Line. The new Park Street Station complex is described under Stage 4 of System I.

The modernization of Boylston Station would take place in this stage.

Traction Power

The following method of power distribution and current collection is proposed to be used for high-platform rapid transit operation--A. On the Riverside Line between the Riverside Station terminal and Bowdoin Station, and B. On the Blue Line via the Boylston Street and Boston Common Subways:

- Riverside Terminal to Fenway Transfer Station--pantograph operation from the overhead catenary system installed in Stage 1.
- Fenway Transfer Station to Bowdoin Station--collector shoe operation from a new third-rail system installed in this stage from Fenway Transfer Station through the existing Boylston Subway to Arlington Station and from Arlington Station to Bowdoin Station through the new Boston Common Subway connection.
- Bowdoin Station to Maverick Station--collector shoe operation from the existing third-rail system.
- Maverick Station to Wonderland--pantograph operation from existing overhead catenary.

Changeover from overhead to third-rail current collectors would be made during station stops at Fenway Transfer Station and at Maverick Station.

Prior to the switchover to high-platform cars in this stage, No. 6 cars of the Riverside Line would continue to operate through the Central Subway to North Station. Since these low-platform cars cannot be run over third-rail territory because of inadequate clearance, installation of the new third-rail system between Fenway Transfer Station and Arlington Station could not be installed while the cars were still in operation.

A solution to this problem would be to install a temporary overhead contact wire system suitable for both trolley pole and slow speed pantograph operation through the present subway between Fenway Transfer Station and Arlington Station. After shifting the No. 6 cars, this system would be used by the high-platform rapid transit cars during installation of a permanent third-rail system. The feasibility of this plan would depend on height and clearances being adequate for pantograph operation.

New substations, in addition to those installed in Stage 1, would be built at Brookline Village and at the combined Beacon Transfer-Fenway Transfer Facility to provide the additional power and voltage regulation required for the operation of the new high-platform rapid transit cars on the Riverside Line between Riverside and a point midway between Kenmore and Auditorium Stations. The present Cooks Junction Substation, with two 1000 kw mercury arc rectifiers and fed from 25-cycle AC power supplied by M.B.T.A. generating stations, would be rehabilitated and increased in capacity. New solid state, silicon diode-type rectifier units and associated rectifier transformers and gear would be installed and the substation fed from new 60-cycle AC power supplied from a local utility company source. The changeover of Cooks Junction Substation would be made while No. 6 cars were still in operation, during which period the peak demand load on the station would be within the limits of one of the two existing rectifier units.

The section of the Riverside Line from a point midway between Kenmore and Auditorium Stations to Arlington Station would be fed from the new Back Bay Substation proposed for the new Southwest Extension of the Orange Line. One rectifier unit and associated equipment would be required in the new substation in addition to the two 3000 kw units proposed for the Orange Line.

The section of the Riverside Line between Arlington and Bowdoin Stations would be fed from the new Dewey Substation proposed for the new Orange and Red Line Systems. Two rectifier units and associated equipment would be required in the new Dewey Substation in addition to the two 3,000 Kw units proposed for the Orange Line and two 3,000 kw units proposed for the Red Line. One set of feeders would be installed to serve this section, running from the substation to the new Park Street Station via the Red Line Subway.

A new overhead contact wire system with supplemental feeders would be installed in the new tunnel connection to the existing Tremont Street Subway. This would enable the new No. 6 cars of the Huntington Avenue Line to operate with trolley pole collectors from the new and existing contact wire systems throughout the route between Brigham Circle and North Station.

Existing direct suspension overhead contact wire distribution systems for the surface operations of the Commonwealth Avenue, Beacon Street and Huntington Avenue Lines would be rehabilitated by installing new contact wire throughout and replacing support poles, pole brackets and span wires wherever necessary to assure smooth operation. The existing No. 2/0 contact wires in the Huntington Avenue Subway would be replaced with No. 4/0 wires, and the present hangers from the tunnel roof would be replaced or adjusted as deemed best for as smooth an operation as permitted by the limited clearances. Feeder capacities in some sections of the routes would have to be increased to keep voltage levels within prescribed limits.

With the Riverside Line power loads removed from existing Coolidge, Newbury, Central, Dewey and North Station substations, sufficient capacity would be available to meet the increased peak loads on the Commonwealth Avenue, Beacon Street and Huntington Avenue Lines caused by the transfer of the No. 6 cars to the Commonwealth Avenue and Beacon Street Lines from the Riverside Line.

The Beacon Street Line would continue to be fed from existing feeder sections as in Stage 2. Power for these sections is presently supplied from the Coolidge and Newbury Substations.

The Commonwealth Avenue Line would continue to be fed from existing feeder sections as in Stage 2. Power for these sections is supplied from the present Coolidge, Oak Square and Newbury Substations.

The New Huntington Avenue Line between Brigham Circle and North Station would be fed from existing substations as follows:

- The section between Brigham Circle and Northeastern Station would be fed as at present from existing Feeder Section 25 which is tied to Coolidge and Newbury Substations.

- The section between Northeastern and Prudential Stations would continue to be fed from existing Feeder Section S-10 which is tied to Newbury Substation.

- The section between Prudential Station and the point of the new tunnel connection to existing Tremont Street Subway would be fed from a new Feeder Section S-9A and tied to Newbury and Central Substations. Feeders

from Newbury and Central Substations presently tied to existing Feeder Section S-9 in the Boylston Subway between Auditorium and Arlington Stations would be extended to the new Feeder Section S-9A. Newbury Substation feeders would be tied to the new Feeder Section S-9A at Prudential Station and to the Central Substation feeders where the new tunnel connects to existing Tremont Street Subway.

- The section between the new tunnel connection to Tremont Street Subway and North Station would continue to be fed from existing feeder sections tied to Central, Dewey and North Station Substations.

Portions of existing Feeder Sections S-1 and S-5 as well as all of Feeder Section S-9 would be disconnected and removed. These now serve the Boylston Subway between Kenmore and Boylston Stations, being tied to Newbury, Central, Dewey and North Station Substations. The existing direct suspension contact wire and feeder systems now serving the elevated structure between Causeway Street and Lechmere would also be disconnected and removed.

Temporary feeder ties installed in Stage 2 from existing Feeder Section S-7 to provide power to the overhead catenary system for the Huntington Avenue Line between Back Bay and South Station would be removed upon installation of new Feeder Section S-9 as described in Item 3 above.

Signals and Communications

The signal system installed in Stages 1 and 2, as described in Chapter 3, would remain in operation during this stage. New interlockings would be installed at the Riverside and North Station Yards.

Telephone and supervisory control systems would be installed between Riverside and Fenway Transfer Stations, between Arlington and Bowdoin Stations, and between Back Bay and Boylston Stations. All systems would be linked to the Dewey Control Center in this stage. Similar installations in the Central Subway in Stage 1 would also be connected to the Control Center. Automatic train dispatching equipment would be installed at Riverside and at North Station.

Rolling Stock and Operations

New high-platform rapid transit cars similar in dimensions to Blue Line cars would be placed in service between Riverside and Wonderland Stations via the Boylston Street, Boston Common and Beacon Hill Subways. These cars would be equipped for dual pickup of traction power--pantograph for overhead power distribution on the surface, and contact

shoes for third-rail power distribution in subway. Car-borne equipment would include a multi-speed cab signal system with overspeed control, with provision for future automatic train control.

PCC cars still operating on the Beacon Street and Commonwealth Avenue Lines would be retired from service and replaced by No. 6 cars from the Riverside Line. The higher maximum speed of the latter would be realized if traffic control were instituted and grade crossings eliminated as recommended in corollary CASS studies of the Beacon Street and Huntington Avenue Lines. The grade crossing problem on Commonwealth Avenue was not studied as part of this report.

Stage 4

General Construction

A section of subway about 5000 feet long would be built between Brookline Village Station on the Riverside-Blue Line and Brigham Circle Station on the Huntington Avenue Line. The new subway would surface east of Brigham Circle Station near Longwood Avenue and the No. 6 cars would run on a route extending easterly from this point in the median of Huntington Avenue.

The Riverside-Blue Line operation through Brookline Village Station would be maintained during construction of the new subway station below. New subway construction under Muddy River between Brookline Village and Brigham Circle Stations would be built in a way similar to this portion of the route on System II. The incline into the median of Huntington Avenue would be built east of Brigham Circle Station. Another incline westerly of the Brookline Village subway station would be built to route No. 6 cars to the Riverside Shops for maintenance if they could not be accommodated in the proposed Dover Street Shops.

Stations

Transfer of passengers between lines would be accommodated in the new Brookline Village Station. This station would have a lobby above the Riverside Line tracks with access into the station from both the new Hearthstone Building on the south side and from along Station Street on the north. Patrons would descend directly from the lobby to either of the two transit lines below--the Riverside Line at surface grade or the Huntington Avenue Line in subway.

Trackwork

A diamond crossover would be built in subway west of the station platforms at Brookline Village Station with sufficient length of tail track to permit four-car trains of new double-end No. 6 cars to change tracks beyond the station platforms before returning to Huntington Avenue.

All track in subway would be fastened directly to the concrete invert as shown on Figure 4-5.

Traction Power

Feeder Section 25 from Coolidge and Newbury Substations which would serve the Huntington Avenue Line between Brigham Circle and Northeastern Station in Stage 3 would be extended in Stage 4 to feed the new section to Brookline Village. A new contact wire system would also be installed in the new subway.

Except for the additional load on the Coolidge and Newbury Substations due to the new Huntington Avenue Line extension, powere requirements in Stage 4 would be essentially the same as in Stage 3. Therefore, the arrangement of new and existing substations as required for Stage 3 would adequately serve the peak demands of the combined operations of high- and low-platform cars in this ultimate stage.

Rolling Stock and Operations

It was assumed that train consist, schedules and operations of Riverside, Commonwealth Avenue, Beacon Street and Huntington Avenue Lines would be the same in Stage 4 as in Stage 3 except that the Huntington Avenue Line would be extended from Brigham Circle to Brookline Village via new subway.

A basic assumption in scheduling construction of the subway between the Riverside and Huntington Avenue Lines at Brookline Village in this stage was that it would be feasible to operate or push No. 6 cars over third-rail territory. The need to do so would prevail from the completion of Stage 3 to the completion of Stage 4 unless No. 6 cars could be maintained in the Dover Street shops.

If No. 6 cars could not operate over third-rail territory in the Boylston Street subway during Stage 3, and maintenance of these cars in the Dover Street shops was found to be impractical, an alternative plan would have to be developed. One solution might be to execute Stages 3 and 4 simultaneously, including construction of an incline westerly of the Brookline Village subway station to permit No. 6 cars to reach the Riverside Shops for maintenance.

ANTICIPATED BENEFITS AND LIMITATIONS

System III attempts to use more fully the existing investment in subways by converting station platforms in the Central Subway to high level, thereby increasing average running speeds. Trains on the Beacon Street and Commonwealth Avenue Lines, however, would be unable to function with high platforms. Their passengers would have to transfer to the Riverside Line near the portals to the Central Subway.

The need to impose transfers on lines where none exist at present is a shortcoming inherent in any system that would convert the Central Subway to high-platform operation, while having cars that operate exclusively at one platform height or the other.

System III as formulated would present no advantage in routing or operations over either System I or System II. Downtown distribution of patrons would be poor. Average walking time would be ten percent greater and corridor-to-corridor travel time five percent greater than in either of the other two systems. Moreover, about 4,300 fewer riders would use this system each day.

Capital expenditures on the Huntington Avenue Line, primarily for new subways under Muddy River and the Massachusetts Turnpike, would be excessive for the 11,000 maximum number of daily riders it would serve.

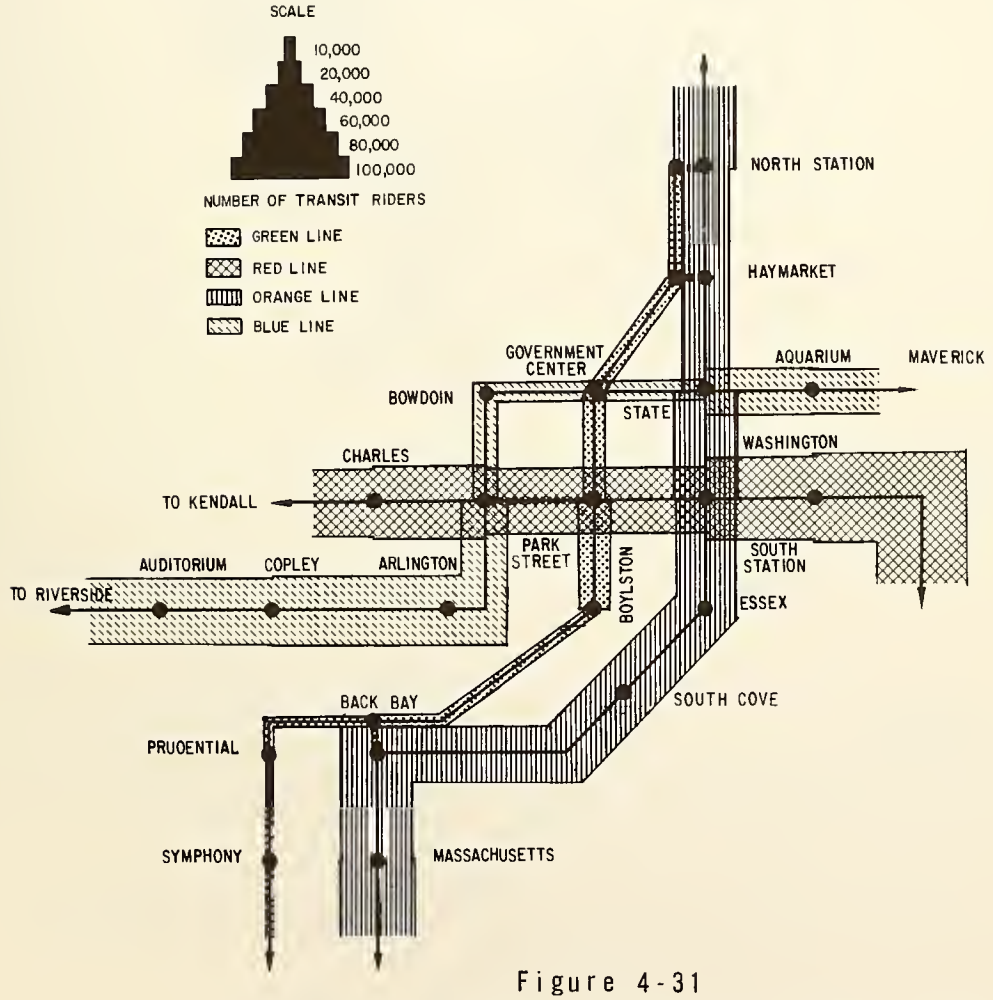


Figure 4-31

ESTIMATED ONE-WAY DAILY TRANSIT RIDERS IN 1990

SYSTEM III

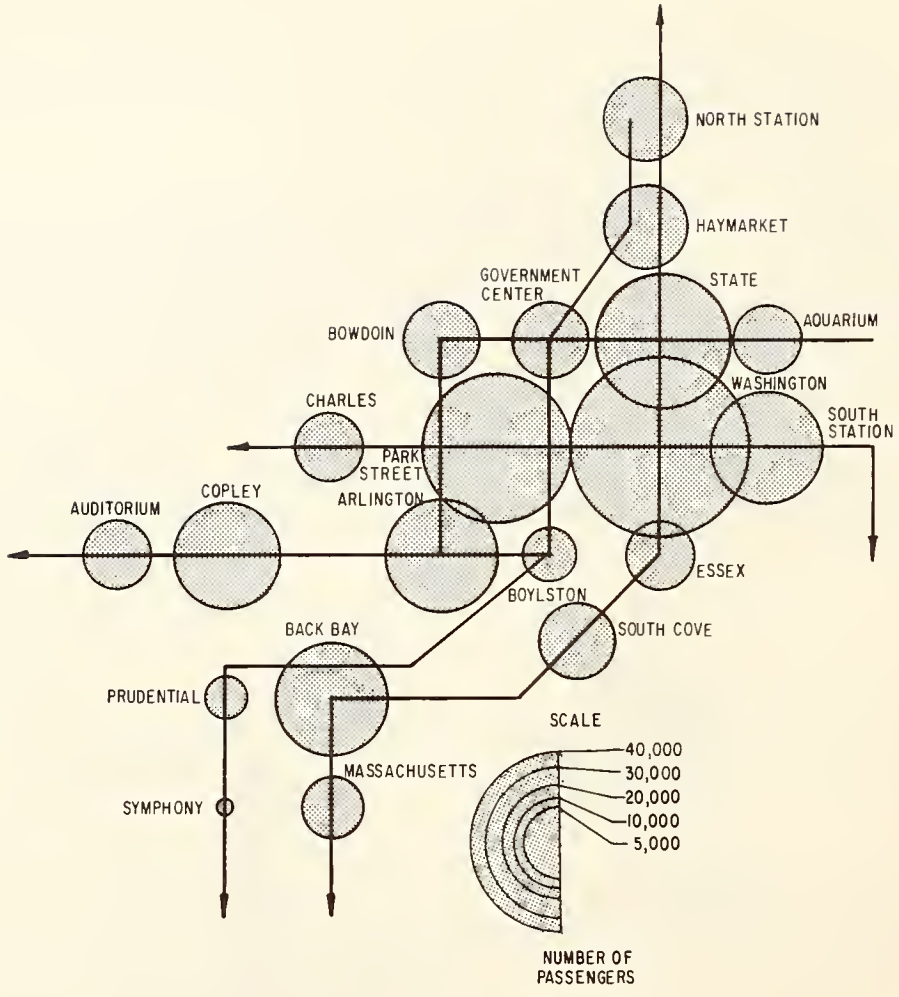


Figure 4-32

ESTIMATED DAILY STATION ENTRIES IN 1990
SYSTEM III

Line volumes and station entries are shown on Figures 4-31 and 4-32, respectively.

Park Street Station would retain its importance as a transfer station, as shown on Figure 4-33, although the total volume of 95,000 daily transfers would be about 17,000 less than for System II.

Back Bay Station would be considerably diminished in importance, since only the Huntington Avenue Line would participate in the 10,000 daily transfers as shown in Figure 4-34.

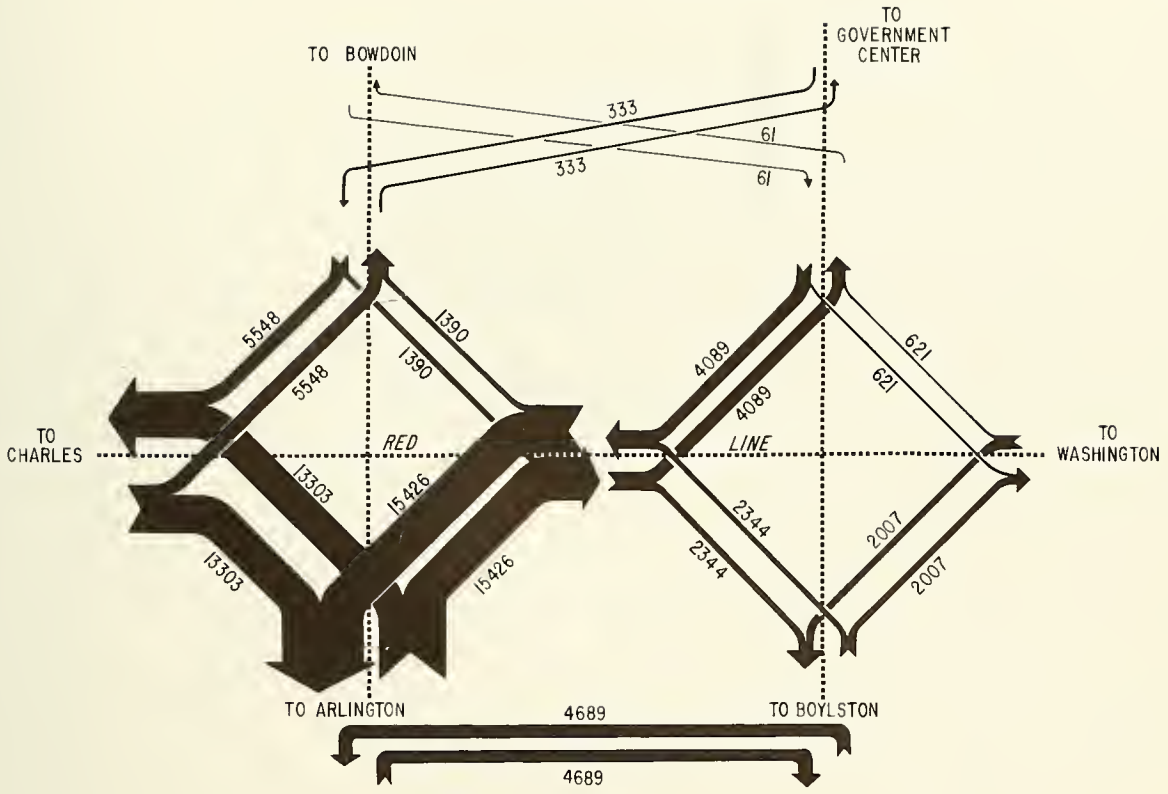


Figure 4-33

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM III
Park Street Station

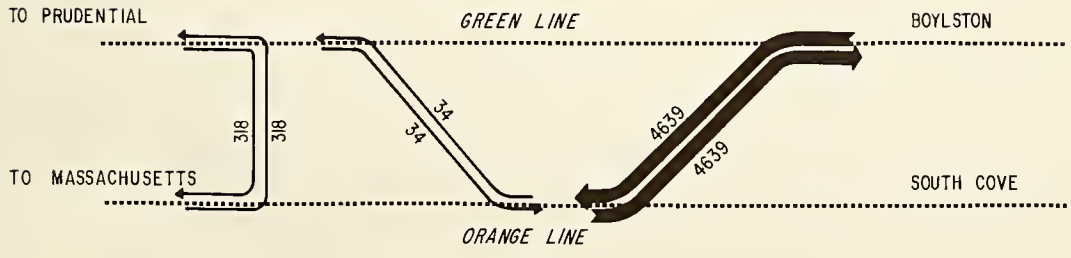


Figure 4-34

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM III
Back Bay Station

State Station on the Orange Line, serving 47,000 daily transfers, would remain a more important transfer point with the Blue Line in this system.

Government Center Station would lose most of its value as a transfer point. See Figure 4-35.

Washington Station would be required to serve 80,000 daily transfers, Figure 4-36, although its capacity is severely taxed by the 35,000 daily transfers it presently serves.

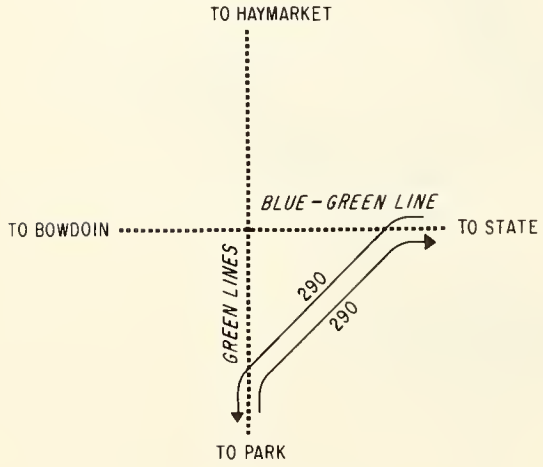


Figure 4-35

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM III
Government Center Station

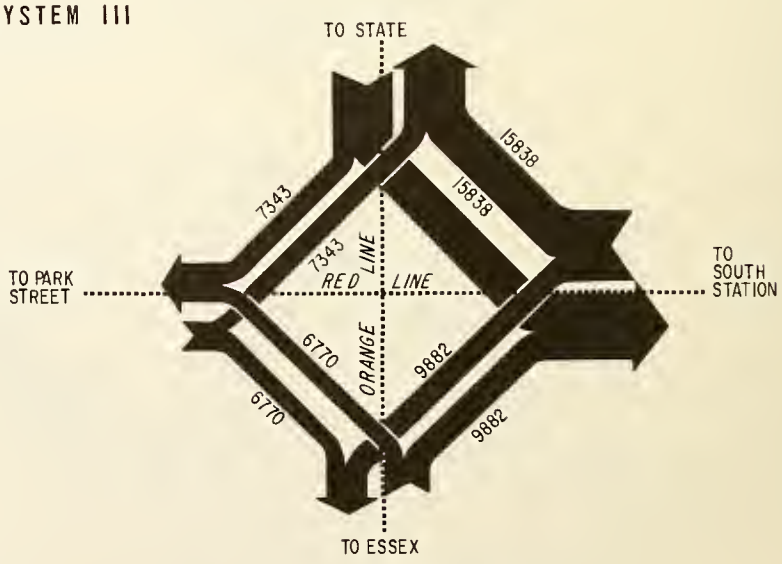


Figure 4-36

ESTIMATED DAILY TRANSFERS IN 1990 - SYSTEM III
Washington Station

Center Plaza Office Building

Chapter 5
ALTERNATIVES STUDIED

MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

Chapter 5

ALTERNATIVES STUDIED

A major part of this study has been concerned with the physical feasibility of specific proposals for improvements to the Green Lines. These proposals were outlined in the Application for a Technical Studies Grant dated May 27, 1968. While these initial proposals were under study, other possible design solutions became apparent, and they were investigated in the study process with the approval of the Authority.

The studies described in this chapter tested the feasibility of various plans. Where applicable, possible alternatives were incorporated in the systems described in Chapters 3 and 4.

OPERATIONAL OBJECTIVES

Engineering design studies were structured to achieve the following operational objectives:

- Fewer train movements in the Central Subway;
- Central Business District routing for the Blue Line via a connection with the Riverside Line;
- Improved power distribution in the Central Subway and the connected Blue Line;
- Improved signal and communication systems on the Blue and Green Lines.

RIVERSIDE LINE ALTERNATIVE ROUTES

Brookline Village to Back Bay Station Area

Three alternative routes were studied for that portion of the Riverside Line between Brookline Village and the Back Bay Station area. These were:

1. Operation along the existing Riverside Line trackage to Park Drive, then in Penn Central Railroad right of way through Brookline Junction, then parallel to the Massachusetts Turnpike, and under Prudential Center to Back Bay Station;

2. Operation in a new subway under the Muddy River and via Huntington Avenue, and connection with the existing Huntington Avenue Subway. The route would continue in either the Penn Central or the New York, New Haven & Hartford right of way, or in a new subway under the Massachusetts Turnpike and Stuart Street;

3. Continued operation over present trackage, with conversion of the Central Subway to permit high-platform rapid transit operation.

Systems I, II and III incorporated these three alternative routes; alternatives were described in detail in the preceding chapter.

Back Bay Station

Back Bay Station Area to Park Street Station

A number of alternative routes for the Riverside Line between the Back Bay Station area and Park Street Station were studied. The Back Bay Station area is of major importance in the transportation network, serving as the gateway to the core area for railway, highway and transit lines from the southwest. Two major railways, the Massachusetts Turnpike and the Central Subway pass through this point. All Green Line trains are routed through the double-track subway under Boylston Street.

The desire to relieve congestion in the Central Subway has led to several proposals for alternative routings of transit services east of Back Bay. The following routes were studied in detail:

- Operation along Penn Central tracks to the reconstructed Tremont Street Subway;
- Operation in a new Stuart Street Subway to the Tremont Street Subway;
- Operation in a new Columbus Avenue Subway.

Alternative 1--Tremont Street Subway

Considered early in the Central Area Systems Study was the reopening of the presently unused Tremont Street Subway. This would be possible if railroad right of way were available and if a new tunnel were built under the Turnpike to link the railroad tracks with the existing subway, as shown on Figure 5-1.

A report entitled, "Tremont Street Subway Extension Engineering Design Study", June 1968, was concerned with the feasibility of such a connection. It was also necessary to determine if construction of the South Cove Tunnel, a portion of the Authority's Southwest Extension project, would interfere with extension of the Tremont Street Subway at a future date. It was concluded that a tunnel connecting with Tremont Street would be feasible, and that South Cove Tunnel construction would be compatible with such a tunnel if it should be recommended in CASS.

Subsequent construction of the Massachusetts Housing Association high-rise apartment complex on Parcel R-5 would modify the route available for the Tremont Street Subway extension. The conclusions of the report would be valid, however, if Scheme 2 of that report were to be selected as the route for the subway extension, and the siting of proposed buildings on that route were modified. The alignment of Scheme 2 was used to route the Huntington Avenue Line via Tremont Street in System III as shown on Exhibits 58 and 59 in Volume III of this report.

The portion of the Tremont Street route between the turnpike and Park Street was studied to determine the feasibility of linking it with a new tunnel between the Park Street and Bowdoin Stations. The double-track subways under Boylston and Tremont Streets meet at Boylston Station to form a four-track subway under Tremont Street running northward from Boylston Street to the loop at Park Street. The PCC cars from the Boylston Street Subway use the two center tracks at Boylston Station. The easternmost track at Boylston Station is the unused northbound track from the abandoned Tremont

LEGEND

- PROPOSED ROUTE
- PROPOSED ALTERNATIVE ROUTE
- EXISTING ROUTE
- PROPOSED TRANSIT STATION
- EXISTING TRANSIT STATION

Figure 5-1

TREMONT STREET ALTERNATIVES

Street Subway which rises at a 4.5-percent grade. The westernmost track is the unused southbound track leading into the abandoned Tremont Street Subway, which descends at an 8.0-percent grade to pass under the Boylston Street Subway. Such grades, combined with 90-foot radius curves, would militate against use of the existing Tremont Street tunnel for rapid transit operation.

In order to connect the unused tracks in the Tremont Street Subway with a proposed tunnel between Park Street and Bowdoin Station, it would be necessary to grade-separate the easternmost track from the other three tracks under Tremont Street since a grade crossing of a rapid transit track and tracks carrying PCC cars would be highly undesirable.

Another constraint on a subway connection from Tremont Street to Bowdoin Station would be the grade of the track in the Park Street Station which rises to the north at a rate of as much as 3.0 percent. The existing Green Line Station lies just below the surface of Boston Common. Below it the Red Line has minimum vertical clearance at the point of crossing. A new station on a connected Riverside-Blue Line would have to pass under the Red Line at Park Street Station:

- To avoid major disruption of the surface of Boston Common; and
- To keep track grades in the new Park Street Station at 0.5 percent or under.

Various ways to do this were studied. The most desirable alignment would involve reconstruction of the Tremont Street Subway from the Boylston Street intersection northward. The new alignment for the Riverside Line would consist of 400-foot radius reverse curves with a profile carrying both tracks under the Boylston Street Subway.

The Green Lines would stop at Boylston Station as at present. The station would be reconstructed with an island platform 320 feet long.

A new subway station would be built under Tremont Street between Common and Stuart Streets to replace Boylston Station on the new Riverside Line route. The entire portion of the abandoned Tremont Street tunnels south of Boylston Street would, therefore, be removed and replaced.

Alternative 2--Stuart Street Subway

One of the earlier proposals to reduce congestion in the Boylston Street Subway was to construct a subway under Stuart Street. This facility was recommended in a 1958 report that included extensive sup-

porting traffic data. Portions of the project as originally proposed are no longer feasible due to reconstruction in Government Center, but the general concept would still be acceptable. The Stuart Street Subway would carry Huntington Avenue Line traffic under the Turnpike and into the unused Tremont Street Subway, thus bypassing Central Subway congestion.

Plans were developed for three routes using the Stuart Street Subway:

1. That portion of the route recommended in the original 1958 proposal from Huntington Avenue to the unused Tremont Street Subway. See Figure 5-2.

2. A route similar to that above, but curving to an alignment west of Tremont Street and parallel to it, passing under the existing Boylston Street Subway. See Figure 5-1.

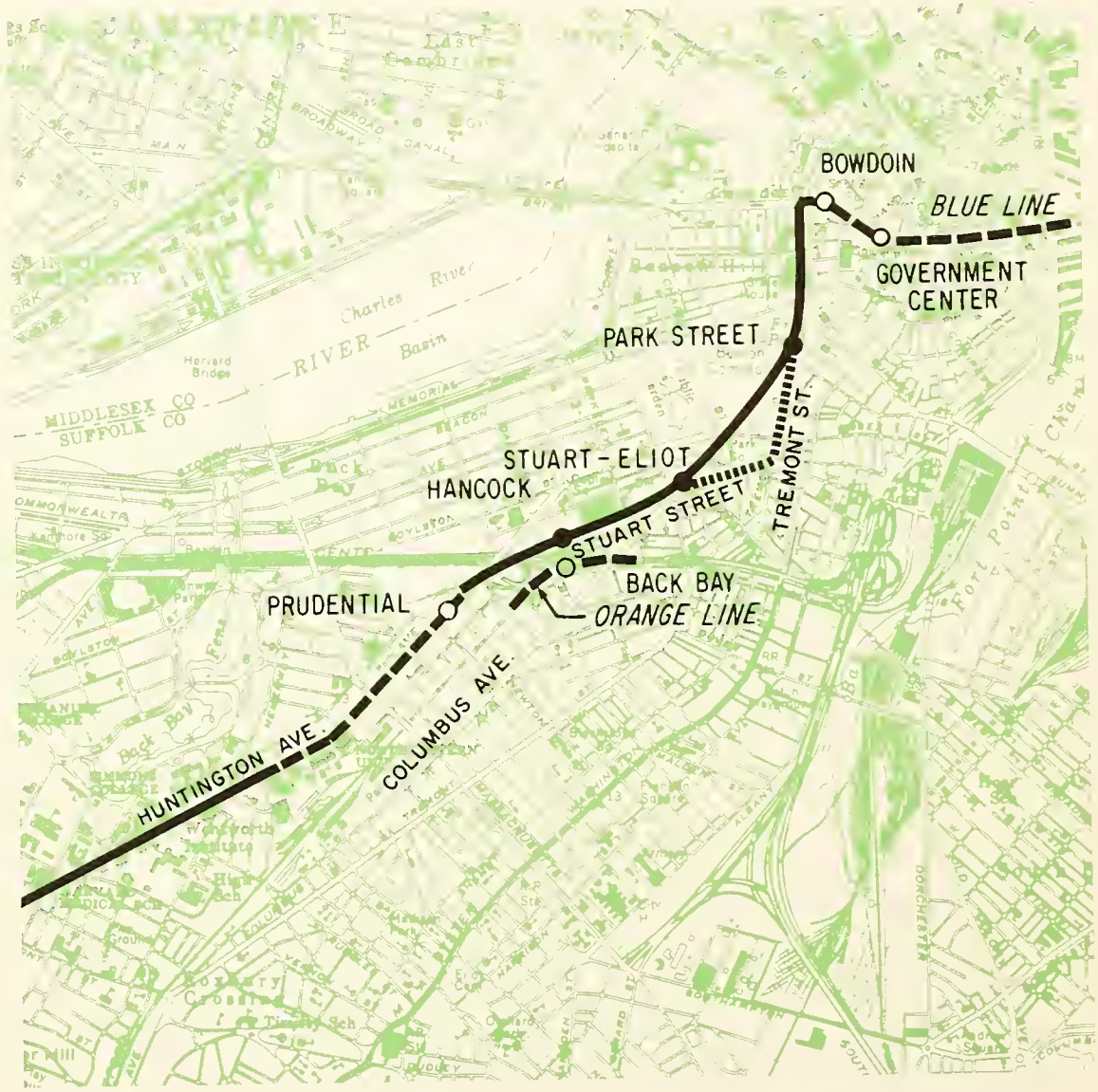
3. A line from Huntington Avenue, extending under Stuart Street and curving northeastward into the Columbus Avenue Subway alignment. See Figure 5-2.

The original Stuart Street Subway plan and profile were modified to adapt them to developments which have occurred since the report was prepared. These included:

- The presence of the Massachusetts Turnpike;
- Construction of the new Hancock Tower;
- Revisions in MBTA clearance and alignment standards.

The Stuart Street alignment would curve away from the existing Huntington Avenue Subway just north of Prudential Station, where platforms would be extended to 440 feet. Twin tunnels about 1,300 feet long would carry the line around the south end of the Huntington Avenue bridge, under the exit ramps, and under the pavement and utility lines of the Turnpike to a station in Stuart Street adjacent to the new Hancock Tower. This station and the remaining portions of the Stuart Street routes would be constructed by cut-and-cover methods. There would be direct access between the new station and the Hancock Building. In addition, free transfer between lines would be permitted at this station. An underground pedestrian passageway equipped with moving sidewalks would extend from the Hancock Station on the Riverside Line to the Back Bay Station on the Orange Line.

A connection could be made with the new subway under Tremont Street previously described. This segment of the alignment would be similar to that recommended in the 1958 Stuart Street report. The



LEGEND

- PROPOSED ROUTE
- PROPOSED ALTERNATIVE ROUTE
- EXISTING ROUTE
- ● PROPOSED TRANSIT STATION
- ○ EXISTING TRANSIT STATION

Figure 5-2

STUART STREET ALTERNATIVES

Stuart Street Subway could be extended eastward via Kneeland Street into the Financial District and the developing South Station area. A study of this alternative should be undertaken.

An alternative to this cut-and-cover subway would be a two-barreled tunnel beginning at Stuart Street and running northward under buildings fronting on Eliot and Boylston Streets, continuing under the Boylston Street Station and the Boston Common to the new tunneled Park Street Station. This route would avoid traffic and utility problems on Tremont Street, but would require underpinning or purchasing and demolishing five commercial buildings.

Another route would connect the Stuart Street Subway with the proposed subway under Columbus Avenue. A subway station would be built in the vicinity of Statler Park. Both the Hancock and Stuart-Eliot Stations would have center platforms 440 feet long with underground mezzanine levels at the midpoint.

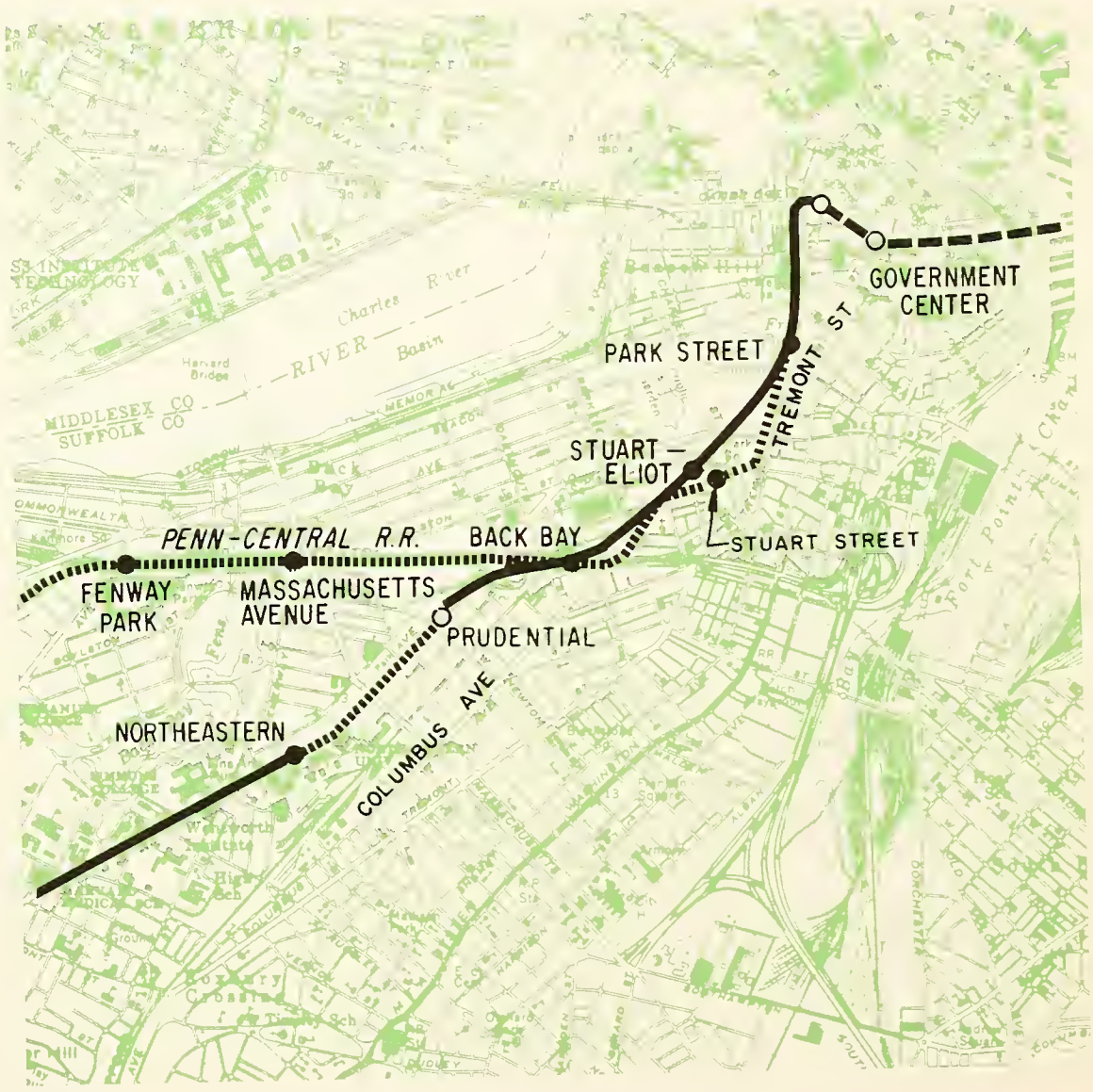
The Stuart Street Subway proposal was investigated thoroughly in the 1958 study. Re-study has confirmed that a subway under Stuart Street would be feasible. A Stuart Street Subway was one possibility weighed, therefore, in establishing a system-wide program of staged improvements.

Alternative 3--Columbus Avenue Subway

The concept of a subway under Columbus Avenue developed as a result of attempts to achieve the following:

- Transit service to the triangle bounded by Boylston Street, the Massachusetts Turnpike and Tremont Street;
- Alleviation of congestion in the Boylston Street Subway;
- Facilities to enable passengers to transfer between the Orange and Blue Lines at Back Bay Station;
- Minimum disruption of normal business activities during construction;
- Connection of the Park Street Station on the Riverside Line with the Blue Line.

Columbus Avenue appears to satisfy all criteria for location of a subway to carry the Riverside Line from Back Bay Station or Stuart Street to Park Street Station. It is a wide street and an extension of its centerline would intersect Park Street Station. The plans for both the South Cove and the Central Business District urban renewal areas indicate that Columbus Avenue will gradually become less important



LEGEND

- PROPOSED ROUTE
- PROPOSED ALTERNATIVE ROUTES
- EXISTING ROUTE
- PROPOSED TRANSIT STATION
- EXISTING TRANSIT STATION

Figure 5-3

COLUMBUS AVENUE ALTERNATIVES

as a traffic artery. For example, the 40-story Eastern Gas Associates Building on the northwest side of Park Square, construction of which has started, encroaches on the former right of way of Columbus Avenue in accord with the revised BRA street pattern for this area. Under the BRA plan, Columbus Avenue will terminate at Stuart Street and become a one-way southbound street between Stuart and Eliot Streets. Columbus Avenue would thus become relatively attractive for underground construction since a minimum of surface traffic would be disrupted.

CONNECTIONS BETWEEN GREEN AND BLUE LINES

Park to Bowdoin Subway

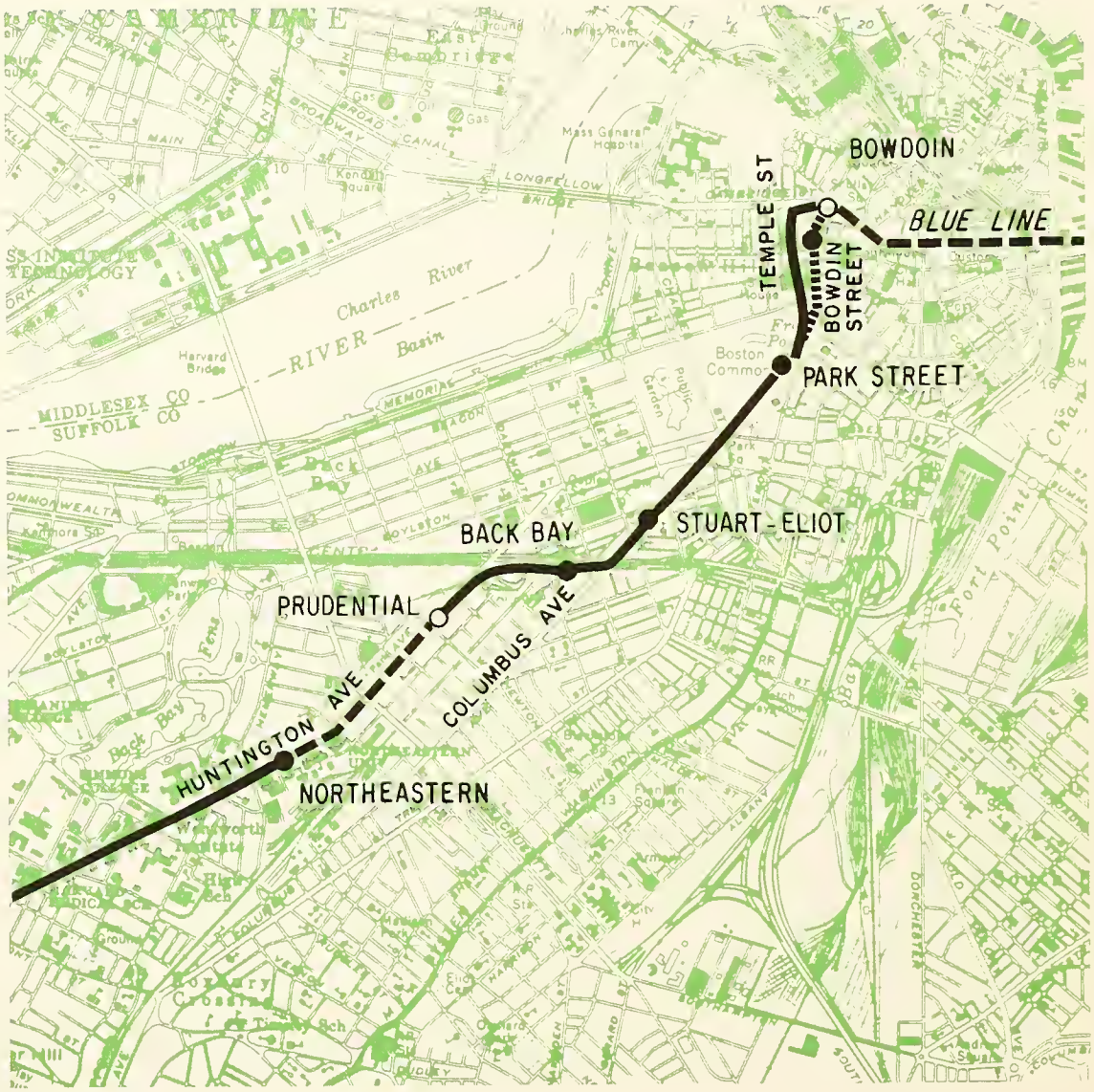
One of the basic objectives of CASS has been to test the advantages of connecting the best of the Green Lines to the Blue Line, thereby creating a new rapid transit line through the Central Area to link the western and the northeastern sectors of the Boston metropolitan area.

A subway under Beacon Hill from Bowdoin Station on the Blue Line to Park Street Station on the Green Line has long been proposed as a possible way to achieve such a through route. While use of the existing Park Street Station structure as a portion of this subway has been proposed, studies indicate that this would be unsatisfactory for several reasons:

- The track in the existing Park Street Station rises on a 3.0-percent grade to the northeast. This is somewhat steep for transit operation;
- Alignment northward from the existing station would require tight curves with attendant low operating speeds as the alternative to razing buildings along Park Street.
- The future passenger volumes at Park Street Station are expected to be much greater than the present platforms would accommodate.

Since a new Park Street Station would be required for the connected Riverside-Blue Line, several possible locations for such a station were studied. That shown on Exhibit 120 in Volume III of this report is favored for several reasons:

- Blue Line passengers would have direct access to trains from the east side of Tremont Street;
- Persons transferring between the Blue and Green Lines would be separated from those transferring between the Blue and Red Lines;



LEGEND

- PROPOSED ROUTE
- PROPOSED ALTERNATIVE ROUTE
- EXISTING ROUTE
- PROPOSED TRANSIT STATION
- EXISTING TRANSIT STATION

Figure 5-4

BEACON HILL TUNNEL ALTERNATIVES

- The number of trip ends east of Tremont Street will be greater than for any other sector of the Park Street Station service area.

Station design to allow end-loading of the Blue and Green Lines platforms is recommended for maximum dispersal of the large number of passengers expected to use this station by 1990.

Two above-ground fare collection structures would serve Park Street Station. One would be in Boston Common at Park and Tremont Streets, replacing the two existing kiosks. This would be the major station structure, allowing direct access from the surface to the Green Line platforms. A second flight of stairs and escalators would take passengers from the Green level directly onto either side platform of the Red Line. The center platform of the Red Line would be removed to allow widening both side platforms within the existing structure, requiring realignment of Red Line tracks at each end of the station. New stairs and escalators from each side platform of the Red Line would lead down to a passageway over the new Blue Line station. From this passageway, patrons would have access to both platforms of the two station tunnels carrying the Blue Line under the Red Line.

The second fare collection structure would be on the east side of Tremont Street south of Temple Place. It would serve the Green and Blue Lines directly through a passageway running under the Green Line and over the Blue Line. From this passageway, a stair and escalator would rise to each side platform of the Green Line and descend to each of the side platforms of the Blue Line.

The subway between Park Street and Bowdoin Station would pass under the intersection of Park and Beacon Streets, under the east wing of the Massachusetts State House, and northward under Temple Street and property fronting on the east side of Temple Street, to a connection with the existing Blue Line Subway at the intersection of Cambridge and New Chardon Streets.

If the subway alignment were moved to Bowdoin Street, the property acquisition along Temple Street could be avoided. The connection to the existing subway west of Bowdoin Station would, however, be more difficult, requiring sharper curves and shortening of the existing platforms.

If reconstruction of the Bowdoin Station were to be considered likely, this alignment would be preferable. If the Government Center loop subway were built, as described below, the reconstructed Bowdoin Station could be located under Bowdoin Street immediately south of Cambridge Street.

Government Center Loop

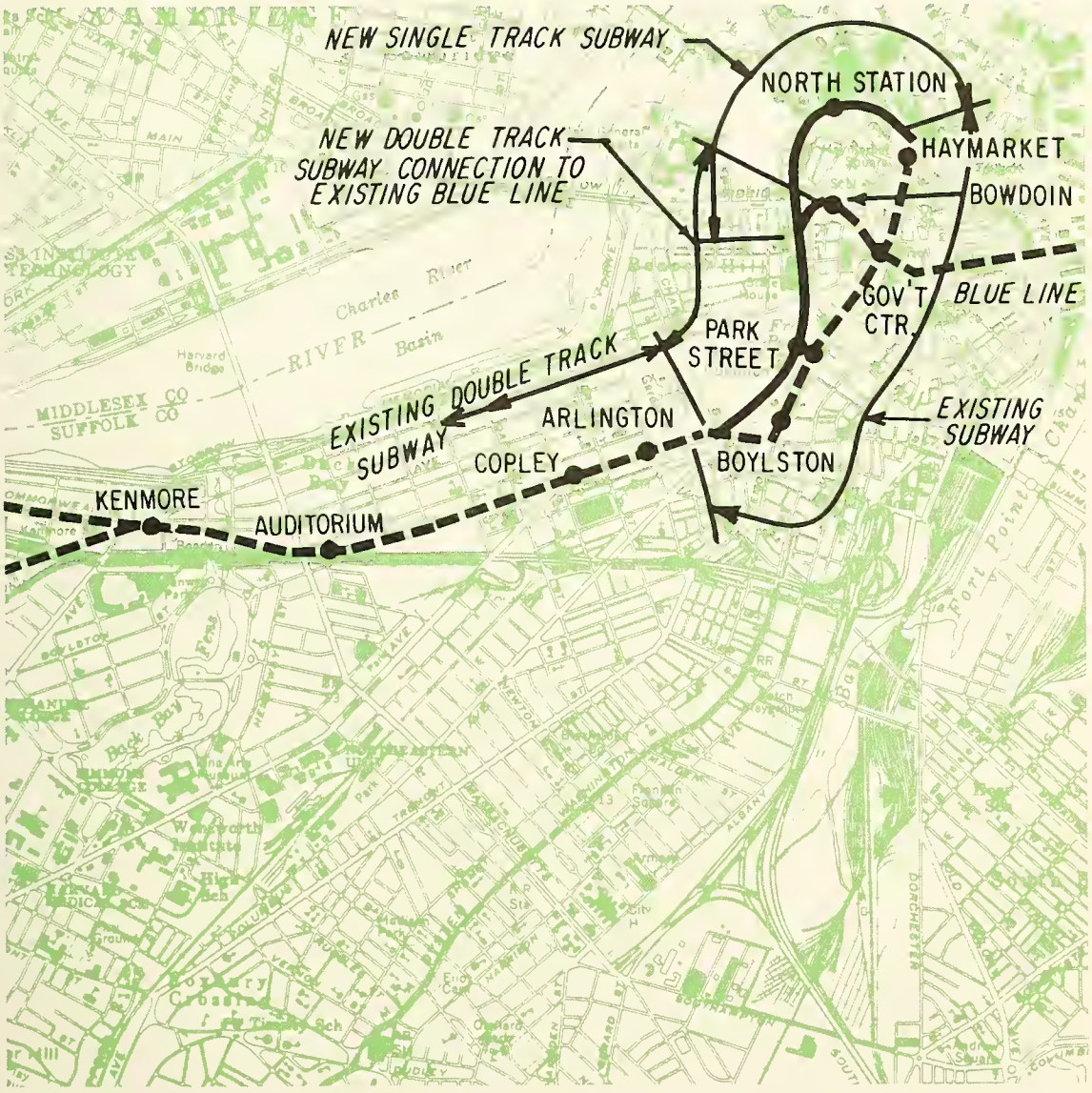
An alternative to System III would split the Green Line into two branches east of Arlington Station. One branch would proceed northward as in System III, through new subway under Boston Common and Beacon Hill to connect with the Blue Line at existing Bowdoin Station. The other branch would continue in the Central Subway as a single-track line, running eastward from Arlington Station to Tremont Street. It would continue northward through Boylston, Park Street, Government Center and Haymarket Stations. Approximately 3,200 feet of new single-track subway would be built from north of Haymarket Station, through a new subway station at North Station under Causeway Street, and under Staniford Street to a connection with the new subway south of Cambridge Street. This concept is shown in Figure 5-5.

This method of operation would have advantages not offered by the other systems. The Government Center Loop would allow more trains to operate to the Western Corridor than to the Northeast Corridor. Traffic data for System III indicates that there will be approximately twice as many trips per day to and through the downtown area from the Green Lines as on the Blue Lines. System III traffic data furnished by the Authority shows a total of 64,000 one-way daily passengers on the Riverside Line and other Green Lines combined at Copley Station, while 37,000 one-way passengers use the Blue Line at Aquarium Station each day. Additional patronage that might be generated by possible extensions to the Western Corridor is omitted from these totals.

A second attribute of the single-track counterclockwise loop is that it would permit direct transfer between the Blue-Green and Orange Lines at Haymarket Station. Transfer between these lines would be possible at Back Bay Station in Systems I and II, but would not be possible in System III without the Government Center loop with split service east of Arlington Station.

The Huntington Avenue Line would be converted for high-platform rapid transit operation and terminated in a new subway station near Northeastern University. Trains on this line would operate around the single-track Government Center loop subway described above, reenter the existing Boylston Street Subway east of Arlington Station, and return to Huntington Avenue via Copley Junction.

The above-described alternative routing of the Huntington Avenue Line would use the existing subway tunnel under the Massachusetts Turnpike, making unnecessary the construction of a new tunnel as proposed in System III. System III would be further modified by deleting both the proposed subway under the Muddy River between Brookline Village and Brigham Circle Stations and the underground storage facility at North Station. Cars could be stored on the unused tracks between



LEGEND

- PROPOSED ROUTE
- PROPOSED ALTERNATIVE ROUTE
- EXISTING ROUTE
- PROPOSED TRANSIT STATION
- EXISTING TRANSIT STATION

Figure 5-5

GOVERNMENT CENTER LOOP SUBWAY

Boylston and North Stations. This operation would be made possible by the similarity of equipment proposed for the Riverside-Wonderland and Huntington Avenue Lines, and by conversion of stations in the existing Tremont Street Subway to high platforms.

The resultant one-way daily passenger volume through the Tremont Street Subway from the combined Riverside and Huntington Avenue Lines would be more than 30,000.

The estimated total saving in capital expenditures from modifying System III as above would be approximately $32,000,000.

Alternatively, the Huntington Avenue Line could be routed to South Station via Back Bay Station as outlined in Stage 2 of System III.

A modification of the Government Center Loop concept was previously proposed by the Boston Redevelopment Authority in a December 1966 report prepared by the Authority's Transportation Engineering Department. The report was entitled "Proposed MBTA System Improvements." It recommended an outside loop carrying two tracks around Government Center from the Tremont Street subway to a connection with the Blue Line at Bowdoin Station. This concept would increase running time for all trains on the Blue-Green connected line by about five minutes, and would lack the potential for balancing line volumes that the single-track loop would offer.

INTERCONNECTIONS TO PROPOSED ORANGE LINE IN VICINITY OF BACK BAY STATION

During the course of this study, the Southwest Extension project proceeded to advanced design stages in early 1969. A subway construction contract was awarded for the South Cove Station just north of the Turnpike. The Authority was commited to the future construction of the South Cove tunnel under the Turnpike to connect New Haven tracks with the existing Washington Street Subway. The new tunnel was seen as a possible opportunity to achieve certain CASS objectives if the tunnel could carry both the Orange and the Riverside Lines through the Central Area.

The feasibility of such an operation was studied. Four alternatives were developed and evaluated:

1. A grade-separated connection in the vicinity of Back Bay Station between the new Orange Line and the Riverside Line, assuming availability of the B&A right of way;

2. Termination of the Riverside Line at Back Bay Station with transfer of passengers to the Orange Line;

3. Continuation of the Riverside Line into South Station, with passenger transfer possible at Back Bay Station;

4. Continuation of the Riverside Line through Back Bay Station into the South Cove tunnel and into the Washington Street Subway, assuming the Orange Line was not yet relocated by the time the South Cove tunnel became available.

The following design criteria were used for purposes of analysis:

- The alignment and profile of the new Orange Line would be that shown on drawings for the Southwest Extension dated January 1969;

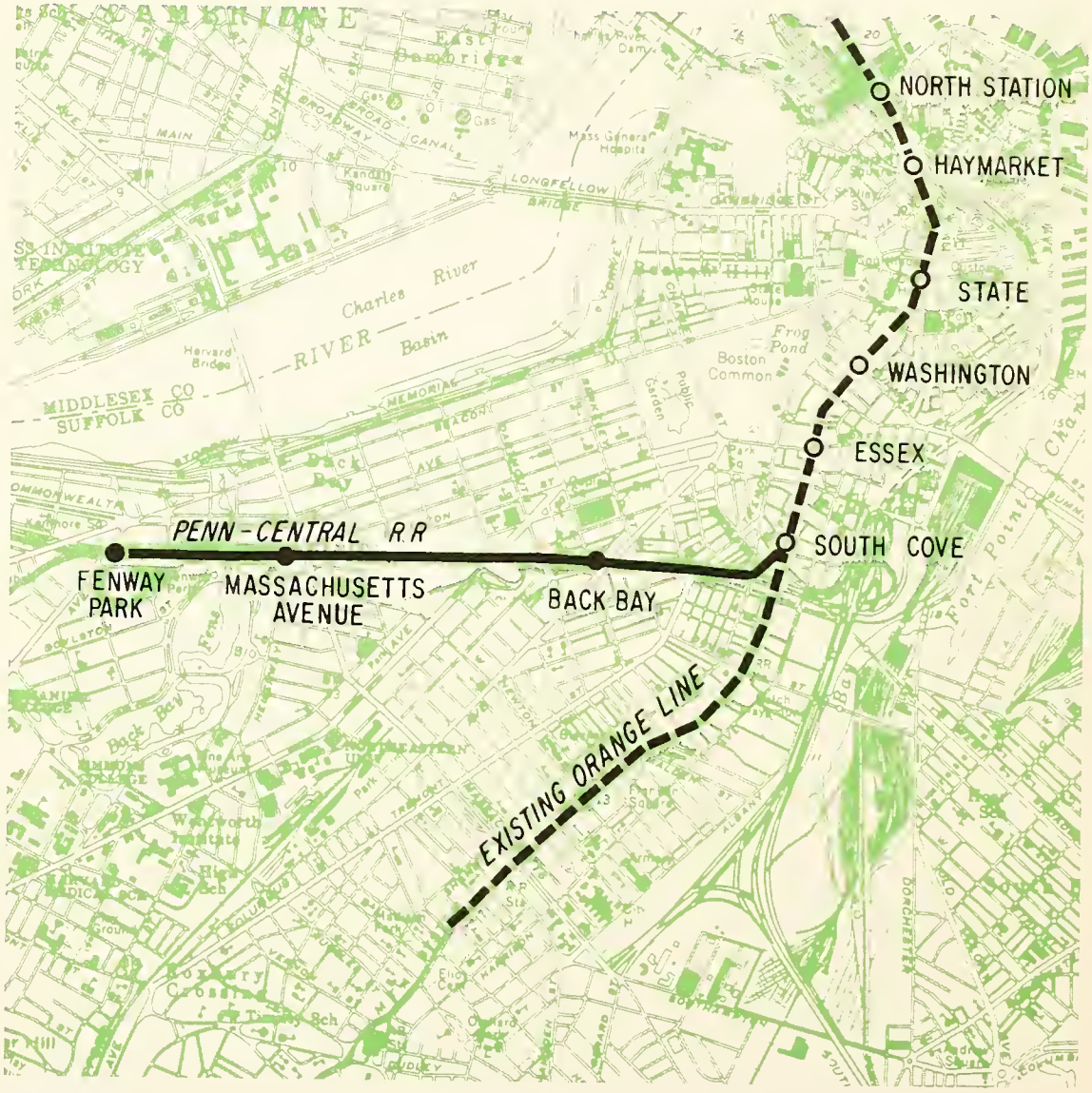
- The Riverside Line Back Bay Station would be at the same grade as the Orange Line. Preliminary consideration was given to building a lower level station at Back Bay with a stub heading under the Turnpike for future construction of the Columbus Avenue Subway; the cost, however, was considered prohibitive. If the Columbus Avenue Subway were to be built, the Riverside Line at Back Bay Station would operate at grade while construction took place at the lower level;

- Power distribution would be by contact rail under Alternatives 1 and 4. Catenary wire or contact rail could be used for traction power under Alternatives 2 and 3, depending on the type of transit car used. Cost estimates were based on catenary construction for Alternatives 2 and 3;

- The contract plans for Project SW-101, the South Cove Tunnel, would be modified only as necessary.

The first alternative--a grade-separated connection between the Riverside and Orange Lines east of Back Bay Station--would be feasible. See Figure 5-6. The inbound Riverside track would descend at Clarendon Street to pass under the two Orange Line tracks near Berkeley Street. The track would rise again to join the Orange inbound track in a widened incline section leading down to the South Cove Tunnel. The Riverside outbound track turnout from the Orange Line would also be placed on the incline west of the tunnel, requiring a further widening of that incline from the original plans for Project SW-101.

Bridges over the railroads on Clarendon Street, Columbus Avenue and Berkeley Street as well as their supporting piers, would be removed and reconstructed. Design of bridges carrying Arlington and Tremont Streets shown on contract plans for Project SW-101 would have to be modified, and it would be necessary to reconstruct a portion of the south abutment supporting these bridges.



LEGEND

- PROPOSED ROUTE
- PROPOSED ALTERNATIVE ROUTE
- EXISTING ROUTE
- PROPOSED TRANSIT STATION
- EXISTING TRANSIT STATION

Figure 5-6

CONNECTION OF RIVERSIDE LINE TO ORANGE LINE

The proposed modificaton of the incline to the tunnel would also require the construction of a siphon for the 54-inch Turnpike main drain. A bypass route for the pipe would no longer be feasible without taking property south of Herald Street.

A grade-separated connection west of Back Bay Station was studied and found to be impractical. Extensive changes to the Back Bay Station as well as ramp modifications, bridge reconstruction and property taking, would be necessary to make such a connection.

Remaining Alternatives 2, 3 or 4 could also be implemented should one of them be deemed desirable.

The termination of the Riverside Line at Back Bay Station (Alternative 2) would require tail tracks and a diamond crossover east of that station.

Continuation of the Riverside Line to South Station (Alternative 3) would be functional with or without the new Orange Line. Power distribution, signals, communications, and station facilities should be designed for the new No. 6 transit cars. Overhead power distribution would eliminate the need for fencing to separate the transit facility from those railroad terminal functions that would continue in the South Station area after start of transit operation.

Continuation of the Riverside Line into the South Cove Tunnel to an at-grade connection with the existing Orange Line (Alternative 4) would be a possibility if the Southwest Extension did not proceed as rapidly as planned. This connection might be made now and severed if the Southwest Extension were implemented at a later date. At that time, a new at-grade junction between the Riverside and Orange Lines might be made near Berkeley Street. Such a junction, however, would have inherent capacity limitations which a grade-separated connection would not have.

NORTH STATION ALTERNATIVES

A major objective of the transit improvement program is removal of elevated structures in the North Station area. One way to achieve this goal would be to construct a new subway or elevated structure between Haymarket Station and the East Cambridge viaduct, renovating the viaduct for retention of service to Lechmere. Another way would be to terminate the Green Lines in the North Station area, discontinuing rapid transit service to Lechmere.

The Orange Line Haymarket-North Extension is presently under construction. Buses now serving Lechmere Terminal on the Green Lines could be diverted to the new Community College Station on the relocated Orange Line.

Lechmere Station serves 8400 passengers per day in each direction. Of these, 5400 transfer to and from buses. Since the Lechmere transit operation is primarily feeder-bus oriented, the Authority believes this line should be diverted to the new Community College Station, thereby improving service. Continued operation of trains on the Lechmere Line would become less important. The remaining 3000 Lechmere Station patrons would also benefit from use of the nearby Orange Line. Neither conversion of the existing East Cambridge viaduct to an exclusive busway nor construction of a new subway to replace the existing elevated structure is recommended. The existing transit corridor to Cambridge should be preserved, however, in view of the study currently under way to determine the potential market for transit service to Somerville. An ultimate plan for new or rearranged transit facilities in this area should be prepared when all essential facts are known.

Exhibit 128 in Volume III of this report shows plans of the proposed Green Line transit terminal at North Station.

EXTENSION OF HUNTINGTON AVENUE SUBWAY TO I-95

The feasibility of this plan for the Huntington Avenue Line would be contingent on relocation of the Orange Line via New Haven right of way between South Cove tunnel and the proposed I-95 expressway median near Roxbury Crossing. It would also be necessary that I-95 and the South End Bypass roadways were built as proposed by others.

The Orange Line Southwest Extension Project proposed three tracks southwest of Back Bay Station on existing right of way of the New Haven Railroad. One of these tracks would carry express trains during rush hours; the other two tracks would accommodate local trains at all times.

If the two Orange Line tracks for local service were rerouted via the existing Huntington Avenue subway and a new subway under Parker Street as shown on Figure 5-7, these benefits would accrue:

- The Huntington Avenue Line would be removed from the Central Subway.
- Property takings for construction of the South End Bypass would be minimized.
- Northeastern University and Wentworth Institute would be accorded excellent rapid transit service.
- Huntington Avenue could be dedicated to street traffic exclusively.

This alternative appears to justify further study.

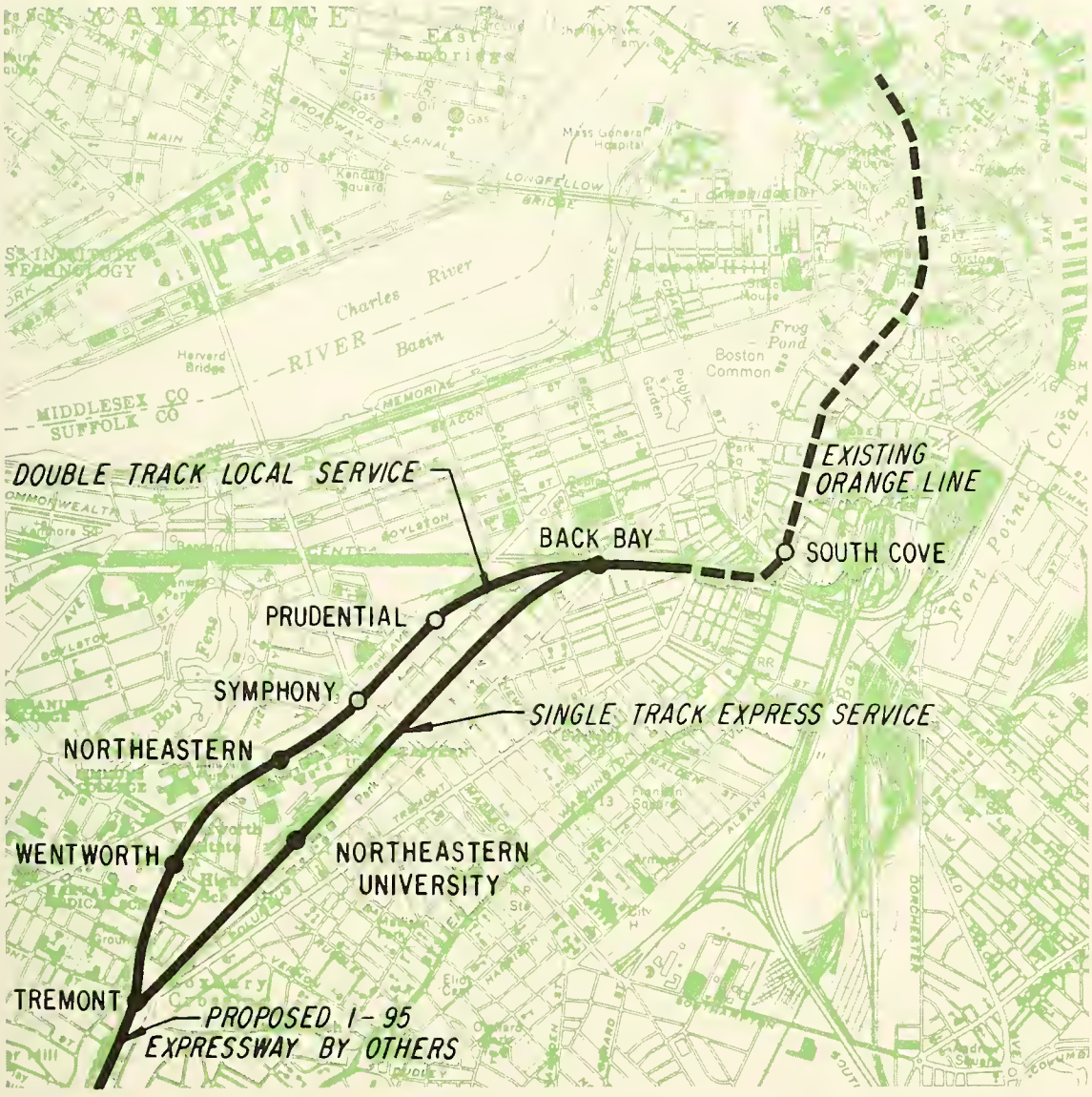


Figure 5-7

HUNTINGTON AVENUE SUBWAY EXTENSION TO I-95

HUNTINGTON AVENUE SUBWAY EXTENSION TO I-695

Short extensions of the existing Huntington Avenue subway were studied. They would terminate either at Northeastern University or at the proposed I-695 Inner Belt Expressway near the Museum of Fine Arts. The latter extension is shown on Figure 5-8.

Traffic studies indicated that rerouting of the Orange Line via New Haven right of way would cause substantial diversion from the Huntington Avenue Line. Daily inbound passenger volume at the subway portal near Northeastern University would decrease from its present 14,400 to an estimated 2,200 by the year 1990, as shown on Figure 4-12. This great reduction in use of the Huntington Avenue Line suggested the advisability of substituting buses for street-running trolleys and terminating the Huntington Avenue rail line at a point suitable for transfer of passengers to buses. A terminal near the proposed Inner Belt would be preferable, but would require a short extension of the Huntington Avenue subway.

An alternative to extension of the subway would be to operate buses on Huntington Avenue and in the existing subway, with passengers transferring at Back Bay Station. This plan would be feasible only if an acceptable propulsion system for motor vehicles in subways could be developed.

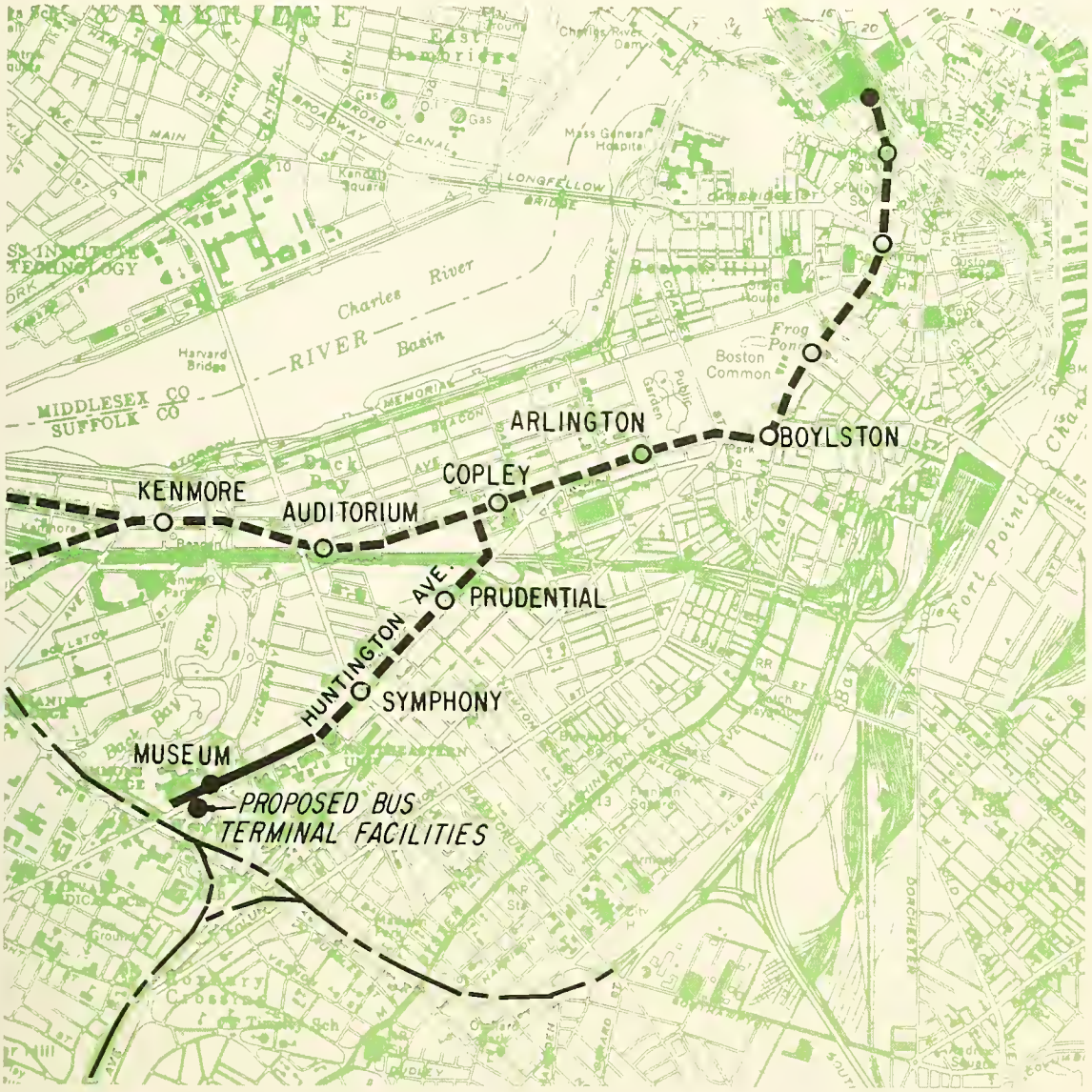
Extension of the subway to Northeastern Station would be an alternative to System III, but only in combination with the Government Center loop concept described above.

CLEARANCE STUDY

Before actually measuring clearances in the Green Line and Blue Line systems with a test car, the Authority found it desirable to examine this aspect of the two lines using mathematical and graphical means. It was recognized that this method of determination should be used only as a prelude to actual test car measurements. The study was conducted, therefore, to obtain a range of dimensions rather than a specific car size. The intent was to cover numerous geometric possibilities to guide the production of a clearance test car and to reduce the number of unknowns involved in design of the new car.

Answers to the following questions were sought:

- Would it be feasible to operate Blue Line cars on the Green Line system (including the Highland Branch)?
- Where are the most critical tunnel sections as regards clearance?

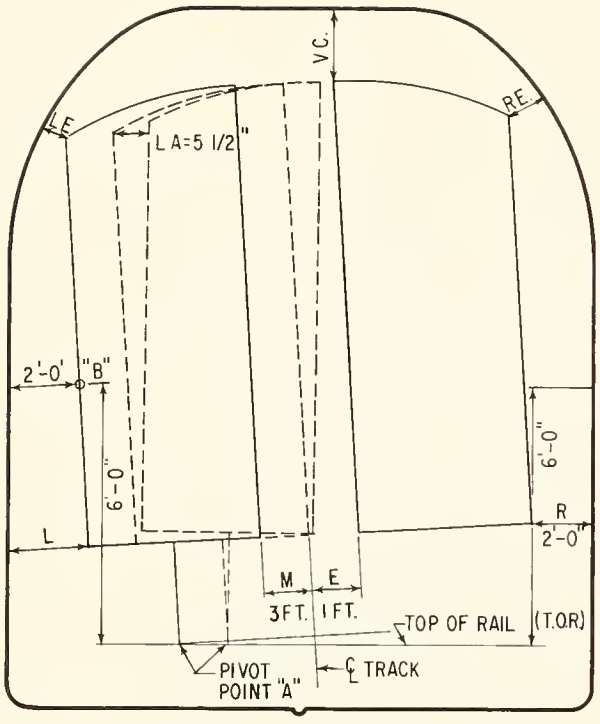


LEGEND

- PROPOSED ROUTE
- PROPOSED ALTERNATIVE
- EXISTING ROUTE
- PROPOSED TRANSIT STATION
- EXISTING TRANSIT STATION
- PROPOSED INTERSTATE HIGHWAY

Figure 5-8

HUNTINGTON AVENUE SUBWAY EXTENSION TO I-695



FOR CURVES TO THE LEFT

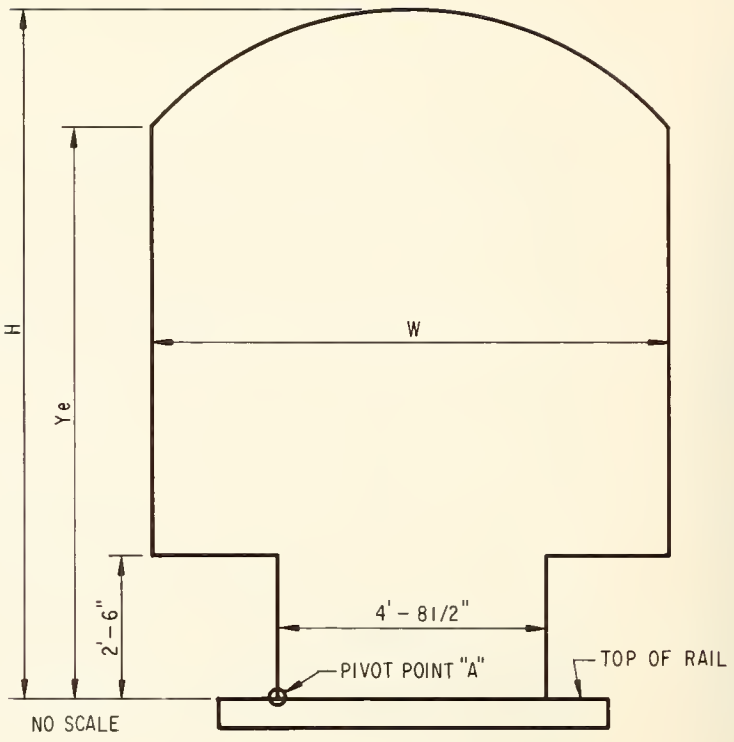
NO SCALE

LEGEND

L E – CLEARANCE AT LEFT EAVE OF CAR
R E – CLEARANCE AT RIGHT EAVE OF CAR
V C – VERTICAL CLEARANCE
L – CLEARANCE AT BOTTOM OF CAR – LEFT SIDE
R – CLEARANCE AT BOTTOM OF CAR – RIGHT SIDE
E – END CAR OVERHANG
M – MID CAR OVERHANG

Figure 5-9

TYPICAL CLEARANCE DIAGRAM



CAR TYPE	HEIGHT (H)	WIDTH (W)	HEIGHT OF EAVES (Ye)
1	12'-0"	9'-0"	10'-0"
2	11'-8"	8'-7"	10'-0"
3	11'-1"	8'-4"	10'-0"
4	11'-1"	8'-0"	10'-0"
5	10'-6"	9'-0"	9'-6"
6	10'-6"	8'-7"	9'-6"
7	10'-6"	8'-4"	9'-6"
8	10'-6"	8'-0"	9'-6"

Figure 5-10

EIGHT CAR TEMPLATE

- What are the dimensions of the largest car that could be operated, under existing conditions, in the Blue Line-East Boston Tunnel (including Government Center and Bowdoin curves)?

- What are the dimensions of the largest car that could be operated, under existing conditions, on the Highland Branch and in the Green Line Subways?

In accordance with the contract, a complete set of 66 drawings and five associated acetate templates were delivered to the Authority.

A graphical method using acetate templates of car outlines was developed to test various trial cross-sections of transit vehicles against the actual clearance diagrams on existing lines.

Data used to test clearances included:

- The cross section of each subway tunnel, plotted to scale (Figure 5-9).
- Acetate templates representing the outline of existing and proposed cars (Figure 5-10).
- Track alignment, superelevation and curve radii.
- Graphs showing relationship between superelevation and lateral adjustment (Figure 5-11).
- Graphs depicting variations between displacement and truck center distances, end overhangs and car lengths versus curve radii (Figure 5-12).

Criteria used for this study:

Either a, Left Eave (LE) = 6"
or b, LE = 1'=2"
or c, Point "B" 2'-0" at 6'-0" above top of rail (Figure 5-9).

Sample Problems Illustrating Graphical Procedures

1. On tangent - For sections on tangent place the acetate template on cross sections and scale clearances.

2. On curves - For sections on curves use the following method:

   a. Given

      i Track alignment on curve of radius, R = 100 feet.

      ii Superelevation E_s = 2.5 inches.

      iii Track curves to the left, CL.

   b. Procedure

      i Enter superelevation on Figure 5-11 and determine lateral adjustment, LA.

      ii Apply lateral adjustment (LA) from Figure 5-11 to left eave line (LE) of template--(Figure 5-9) by rotating template about pivot point "A", Figure 5-10.

iii Slide pivot point "A" (Figure 5-10) of template to the left along line T. O. R. (Figure 5-9) to desired clearances.

iv Scale M on Figure 5-9.

v Enter M on Figure 5-12 and project to given radius (R) and read truck center distance.

vi Slide point "A" (Figure 5-10 of template to the right along T. O. R. (Figure 5-9) to desired clearance.

vii Scale "E" (Figure 5-9).

viii Add "E" to "M" and enter on Figure 5-12. Project to given radius (R) and read car length.

ix See tabulation below for summary of results.

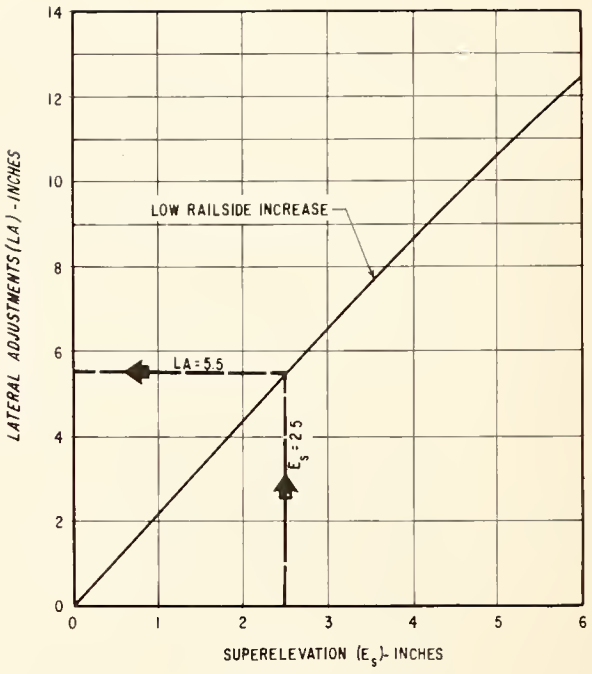


Figure 5-11
LATERAL ADJUSTMENT DUE TO SUPERELEVATION

TABULATION OF RESULTS

LA = 5.5 inches
(Figure 5-11)

M = 3 feet (Figure 5-12)

TCD = 48 Feet
(Figure 5-12)

E + M = 1 + 3 = 4 feet
(Figure 5-12)

L = 57 feet (Figure 5-12)

Reverse above procedures pertaining to Figure 5-12 to establish clearances for cars presently operating (Blue, Green, Red and Orange).

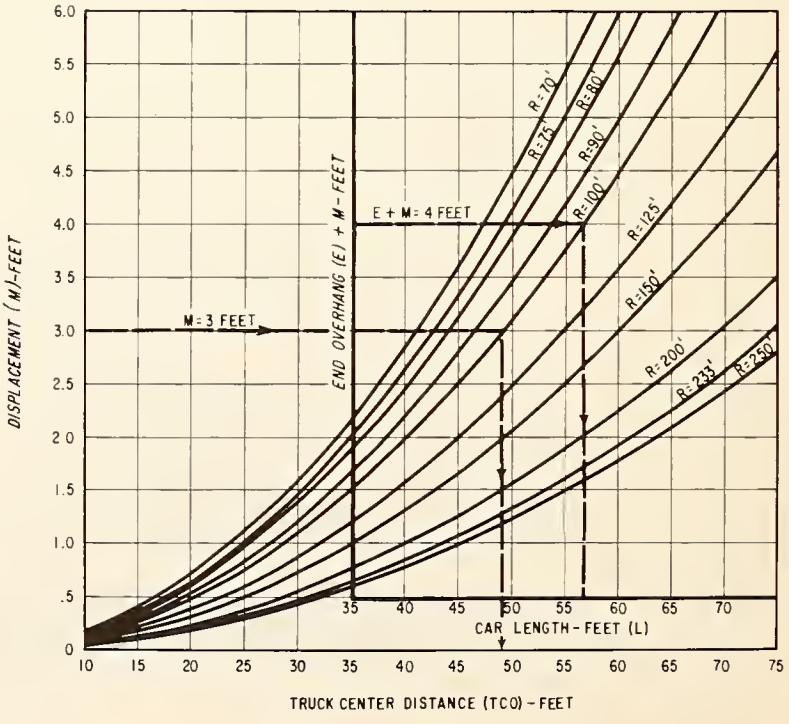


Figure 5-12
DISPLACEMENT DUE TO TRACK CURVATURE

Results and Conclusions

Almost without exception, the narrowest theoretical cars produced the largest potential floor areas since more length would be permissible due to greater mid- and end-car overhangs.

Green Line

All test sections on the Green Line, including the Highland Branch, are tabulated below with the most critical clearance section listed first and others in descending order:

Order No.	Location
1	Easterly track, Washington and Hanover Streets.
2	Easterly inbound track, Government Center Station.
3	Westerly track, Park and Tremont Streets.
4	Tremont Street Sub-subway.
5	Westerly inbound track, Government Center Station.
6	Westerly inbound track, Washington and Hanover Streets.
7	Huntington Avenue Subway at Boylston Street.
8	Inbound tunnel at Tremont and Boylston Streets.
9	Highland Branch near Cypress Street.
10	South track, Boylston Street Subway near Kenmore Square.
11	North track, Boylston Street Subway near Kenmore Square.
12	Highland Branch west of Washington Street in Brookline.
13	Highland Branch at Aspinwall Avenue.
14	Highland Branch at Longwood Avenue.
15	Highland Branch at Chestnut Hill Avenue.

Each of the above sections may be identified in Volume III of this report. The easterly track at Washington Street and Hanover Street and the inbound track at the Government Center Station are not in use at present. If these two sections were deleted from the list, Section 3, the westerly track at Park and Tremont Streets, would become the most critical.

Testing of cross sections of the Green Lines using the No. 3 Blue Line car template showed that, with minor modifications of the track, the Blue Line car could operate over the existing Green Line routes. At critical sections, such as Section 3 in the above table, minimum clearances of only ten inches between car and subway structure would exist.

In the Tremont Street Sub-subway, if the tracks were lowered and shifted laterally, adequate clearances could be obtained. This shift might require direct fastening of the track to the existing concrete invert.

Minimum lateral clearance in the Boylston Street Subway was found to be more than one foot. A graphical check of clearances on the Highland Branch disclosed that Blue Line cars would meet clearance requirements.

Blue Line

The most critical section on the Blue Line was found to be the loop at Bowdoin Square. The next most critical sections were in the East Boston Tunnel at Devonshire Street and under Boston Harbor.

Subsequent to submission of the Graphical Clearance Studies report on April 8, 1969, a clearance test car was built by the Authority. Tests were performed in the Central Subway during May 1970, using the configuration of the proposed No. 6 car. See Volume I of this report for results of the clearance car runs.

ROLLING STOCK

One of the tasks of the Central Area Systems Study was to investigate alternative types of rolling stock for the Riverside Line and the remaining Green Lines. This work item was stated in Section III-9 of the Application for a Technical Studies Grant dated May 27, 1958, as consisting of:

> "Determination of the desired design characteristics and dimensions of new vehicles for the Riverside Line, Blue Line, and for the balance of the Green Line, compatible with the recommended long-range plan for the Central Area System."

Reduction in the number of different types of cars would benefit the Authority by reducing maintenance and operating expenses. Transit operators have often foregone optimization of size for routes of different characteristics to obtain savings through standardization. The Authority's directive to design all underground structures to comply

with the No. 5 Red Line car clearance diagram indicates a desire for standardization of vehicles.

Vehicle selection was approached in the same way as other portions of this study; that is, the goal was to find an ultimate solution rather than to produce a plan that would provide only short-term benefits. Several intermediate stages leading to what is deemed to be an ultimate solution are described below.

Modification of PCC Cars

The Authority and others have studied ways to modify PCC cars to improve their operating characteristics. Current problems with these cars and proposed modifications are discussed in Chapter 3.

Possible modifications promised to be costly and difficult, and they would still leave the cars with many shortcomings.

No program of modification or renovation of aging PCC cars should be adopted. Instead, new transit vehicles which would meet current and anticipated needs of the Green Lines should be purchased.

Proposed New No. 6 Cars

The deteriorating condition of PCC cars on the Green Lines led the Authority to search for replacements. The Authority decided to develop a new transit car capable of operating from low level platforms only. Two of the Green Lines were proposed to be completely equipped with such cars--the Riverside Line and the Huntington Avenue Line. This would take approximately 130 cars to fill schedules in peak periods. During off-peak hours, some of the cars were to be used on the other Green Lines.

The Consultant advised the Authority on several aspects of No. 6 car design including power collection, clearance, operating speed, and signals and communications.

The trolley poles for No. 6 cars were designed to permit operation on street-running portions of the Green Lines without requiring major reconstruction of the overhead power distribution systems.

Clearances on existing routes were determined by means of a graphical procedure developed by the Consultant. This study permitted the Authority to establish preliminary dimensions of the proposed car. Subsequently, a clearance test car was built and used to measure actual clearances in existing subways. Theoretical speeds were determined for the Riverside Line to establish desirable speed characteristics of the proposed No. 6 car. Actual test runs under simulated operating conditions later confirmed the validity of the computations.

The Consultant recommended a multi-speed cab signal system with overspeed control and automatic car identification for the new No. 6 cars. All PCC cars to remain in service would also be so equipped. The No. 6 cars would have both intercommunication equipment and radios. Retained PCC cars would be equipped with two-way radios only.

A detailed description of No. 6 car specifications is contained in Volume I of this report.

All recommendations in the Stage I Immediate Action Program listed in Chapter 3 were based on the use of the new No. 6 car. Systems I, II and III also incorporated the use of No. 6 cars, as described in Chapter 4.

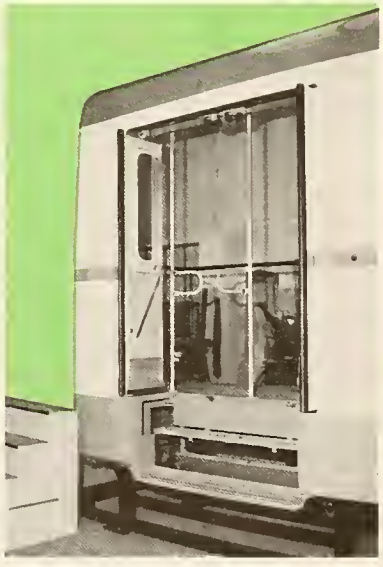
High-Low Platform Convertible Cars

The Consultant's recommendations in Chapter 1 were based on a given set of conditions, one of which was the Authority's selection of a new Stage 1 transit car.

Given a different set of conditions, one of them being a convertible and/or articulated transit vehicle, the Consultant's recommendations might also have been different.

If the No. 6 cars had already been built, any discussion of alternative vehicles would be futile. Since the No. 6 car is still in the development stage, however, it is appropriate to examine the potential benefits of having a car that could operate on both high- and low-platform routes.

Doors open adjacent to high-platform



Doors open adjacent to low-platform

Doors closed

These benefits are foreseen:

- Passengers could board and alight from trains faster at high-level platforms. This would be especially advantageous in the Central Subway.
- Lines would not have to be separated into street-running and rapid transit systems. The forced transfers indicated in System III, therefore, would be unnecessary.
- The cars operating with low platforms in streets could also operate from high platforms on the Riverside Line and in the Central Subway.
- A similar car could replace present Blue Line cars and compatability of equipment on the two lines when a Blue-Green connection is made would be assured. This would be a step toward standardization of rolling stock. The performance characteristics of this car, however, would not equal those of a modern rapid transit car.
- Early construction of high platforms in higher-volume stations would be possible.
- Staged construction of high platforms under traffic would be simplified.
- Extensions beyond the present terminus would be simplified and economically attractive. See Western Corridor Studies, Chapter 6.

The Systems presented in Chapter 4 would be enhanced by the use of a convertible vehicle. Since System III would change the Central Subway to high-platform operation, it would benefit most directly from this change.

Initially the Green Lines would operate in the following manner:

- Riverside Line trains would run high-platform on the Highland Branch and in the Central Subway.
- Huntington Avenue, Beacon Street and Commonwealth Avenue Line trains would function from slightly raised platforms on surface portions of their routes, changing to high-platform operation in subway.
- The Lechmere Line could continue as a low-platform operation.

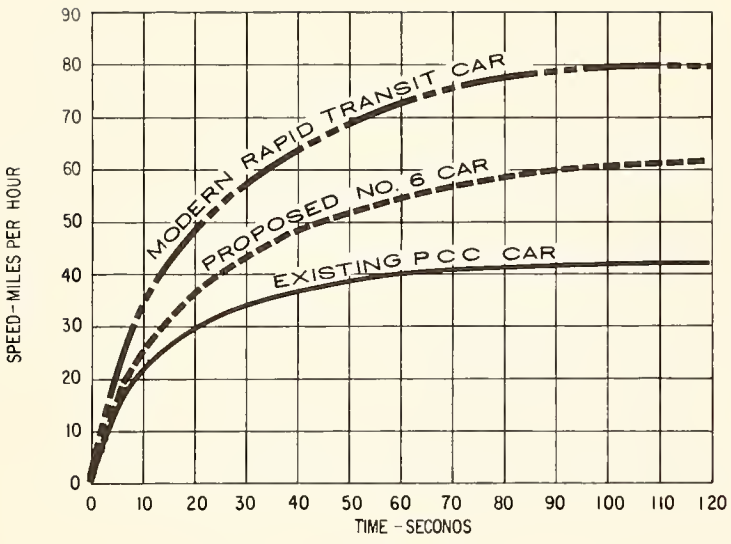


Figure 5-13
SPEED-TIME CURVES

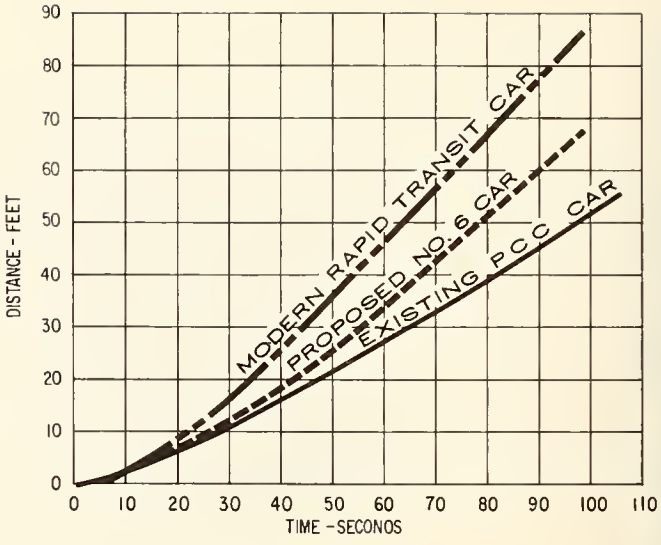


Figure 5-14
DISTANCE-TIME CURVES

When the Green and Blue Lines were connected and the Orange Line relocated, continued operation of the Huntington Avenue Line through the Central Subway could be evaluated on the basis of previously discussed alternatives for this Line.

Maintenance costs for a convertible vehicle would probably be higher than for a more conventional car. New maintenance shops proposed for construction at Riverside in Stage I, however, could be equipped to maintain such cars. Potential benefits from use of convertible cars are considered to outweigh the possible increased cost of maintenance.

High-Platform Rapid Transit Cars

Projected volumes on the Riverside Line would approach 60,000 passengers per day in each direction by 1990. About 6000 additional passengers would move in each direction between downtown transit stations on this line. Passengers to Logan International Airport are not included. Since approximately 30 percent of the daily passenger flow occurs during the peak hour, about 20,000 passengers per hour would move over a single track. This volume would justify consideration of high-capacity, high-performance vehicles such as those used on other rapid transit lines in the Boston metropolitan area.

A modern rapid transit vehicle has been proposed, therefore, in the later stages of the systems described in Chapter 4. It would have a floor at station platform height, ample doors for fast loading, and high performance characteristics as shown in Figures 5-13 and 5-14.

Conclusions

The study of various types of transit vehicles led to the conclusion that:

- PCC cars do not meet existing and projected needs of the Green Lines.
- Development of the No. 6 car should be re-examined for possible inclusion of a convertibility feature.
- The long-range solution to the vehicle selection problem would be a modern rapid transit car.

The operating characteristics of the three vehicles were applied to the Green Lines to determine running times, time savings, and optimum speeds on alternative routes. This information was used by the Authority to establish the numbers of new vehicles required and the cost of operating them.

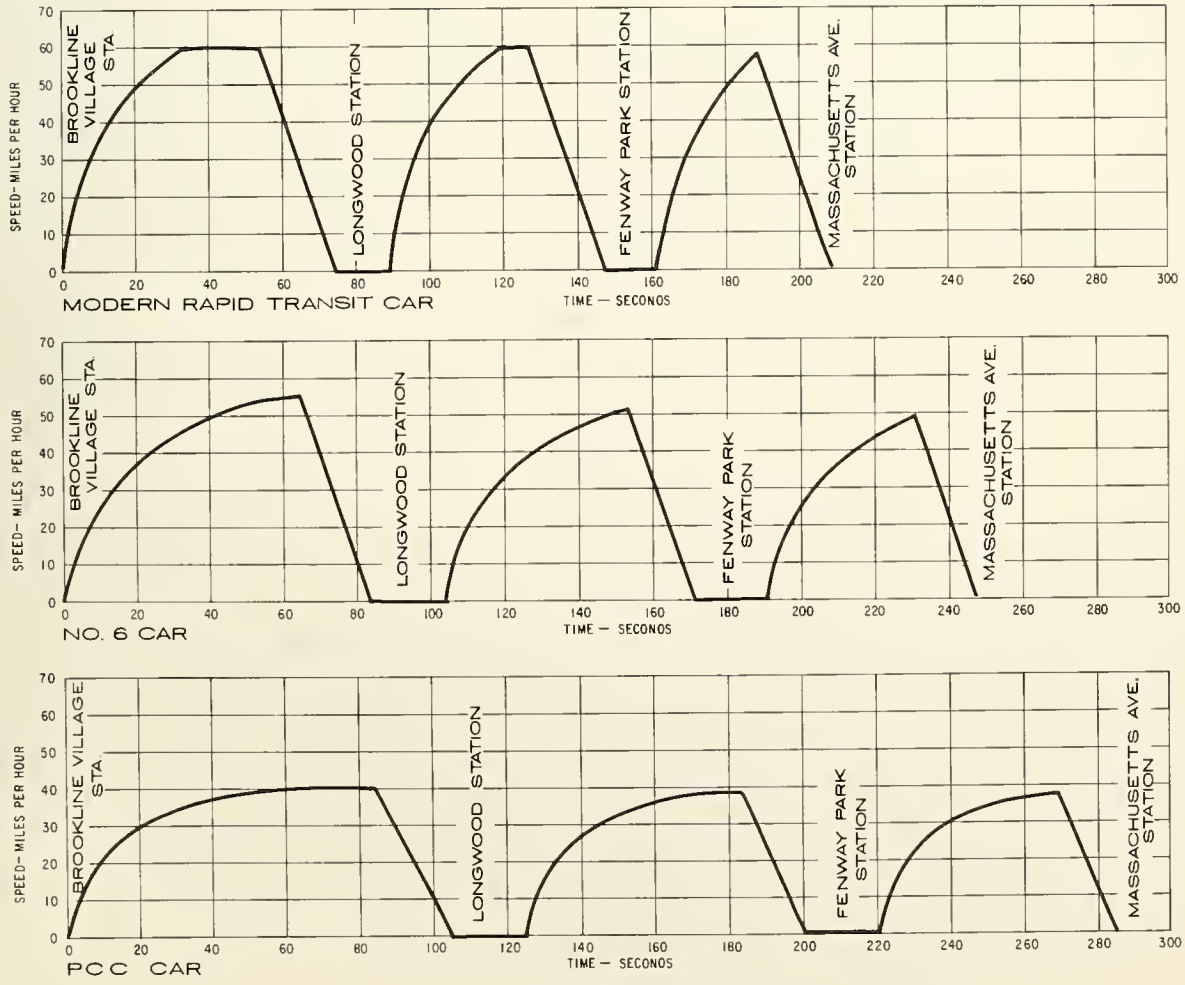


Figure 5-15

COMPARISON OF ELAPSED TIME USING VARIOUS TRANSIT CARS

The performance characteristics of three types of transit cars were used to compare elapsed time between two points on one of the proposed Riverside Line routes. This comparison is illustrated on Figure 5-15. An existing PCC car would make the run between Brookline Village Station and the proposed Massachusetts Avenue Station in 285 seconds, with intermediate station stops at Longwood and Fenway Park Stations. A new No. 6 car would make the same run in 247 seconds, saving 13 percent of the original running time, while a modern rapid transit car would use 208 seconds, with a 27 percent saving in running time.

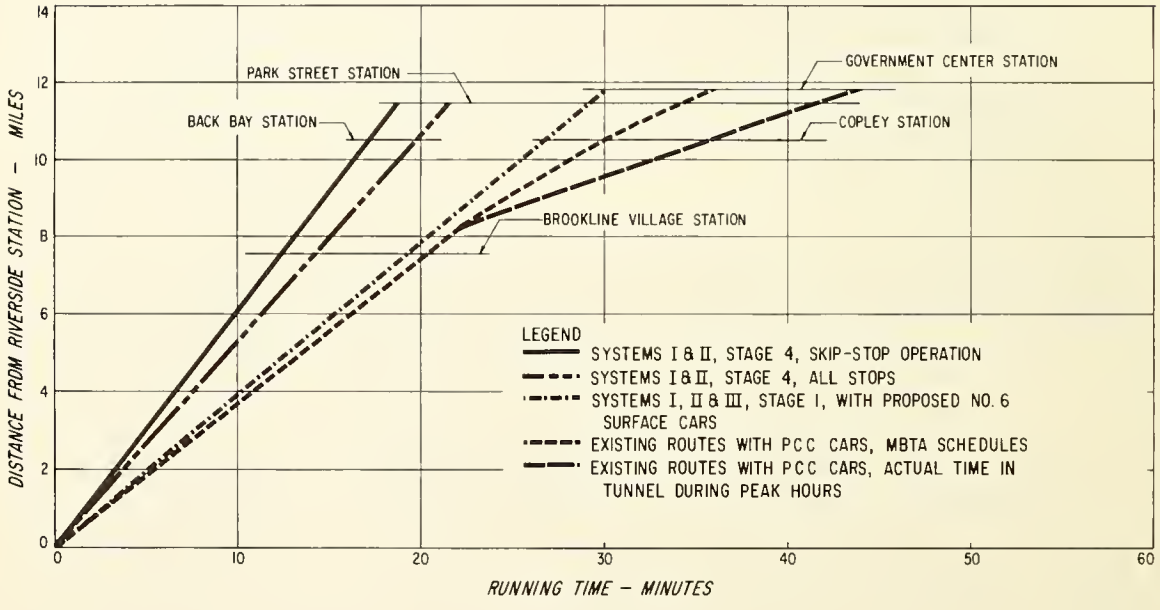

DISTANCE FROM RIVERSIDE STATION - MILES
RUNNING TIME - MINUTES
PARK STREET STATION
BACK BAY STATION
GOVERNMENT CENTER STATION
COPLEY STATION
BROOKLINE VILLAGE STATION
LEGEND
SYSTEMS I & II, STAGE 4, SKIP-STOP OPERATION
SYSTEMS I & II, STAGE 4, ALL STOPS
SYSTEMS I, II & III, STAGE 1, WITH PROPOSED NO. 6 SURFACE CARS
EXISTING ROUTES WITH PCC CARS, MBTA SCHEDULES
EXISTING ROUTES WITH PCC CARS, ACTUAL TIME IN TUNNEL DURING PEAK HOURS

Figure 5-16

RUNNING TIMES BETWEEN RIVERSIDE AND CENTRAL AREA

Running times on the Riverside Line are shown on Figure 5-16. A train of PCC cars needs 44 minutes to run between Riverside and Park Street Stations during peak periods, although scheduled time is only 34 minutes. New No. 6 cars would reduce this time to about 29 minutes in Stage 1. Modern rapid transit equipment in Stage 4 of Systems I or II would make the run between Riverside and Park Street Station in 21.5 minutes making all stops, and in 18.5 seconds using skip-stop operation. The run from Riverside to Park Street Station could, therefore, be made in less than half the time it now takes.

The State House

Chapter 6
WESTERN CORRIDOR

MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

Chapter 6

WESTERN CORRIDOR

The original Central Area Systems Study was directed toward improvement and modernization of the Central Subway and Highland Branch. It also was initiated to determine the feasibility of linking and through-routing the Riverside Line in the Western Corridor and the Blue Line in the Northeast Corridor.

The revised Master Plan contained a proposal for further extensions of rail rapid transit lines in both the Western and Northeast Corridors. Because of the close association between the CASS project and the Western Corridor, the original study was expanded to include the Western Corridor extensions. All alternatives studied were based on the premise that no new routes outside of existing railroad rights of way would be considered.

The Western Corridor study included physical feasibility and cost estimates of:

- Extending rail rapid transit over the Penn Central Company main line (formerly the Boston & Albany Railroad) from the Riverside terminal to the Wellesley-Natick-Framingham area compatible with the use of either the Highland Branch or the Penn Central main line from Riverside to the Fenway Park area.

- Extending rail rapid transit from Needham or Needham Junction to Cooks Junction on the Highland Branch using the Penn Central Charles River Branch (formerly The New York, New Haven and Hartford Railroad Company, Charles River Branch).

- Extending rail rapid transit over the former Boston & Albany main line from the Riverside terminal to the Fenway Park vicinity.

A fourth investigation included study and evaluation of the most practical use of the Riverside Line (Highland Branch) right of way and facilities in view of Study Items 2 and 3. See Figure 6-1.

RECOMMENDATIONS

Early in the study it was determined that the Western Corridor investigations would have to be concurrent and compatible with objectives of the original Central Area Systems Study.

Two independent systems based on the availability of Penn Central rights of way for MBTA operation were formulated.

System A assumed that:

- The Boston & Albany tracks between Fenway Park and Riverside would not become available for transit use;

- Two unused track sections--the southerly two-track portion of right of way from Framingham to the Riverside terminal vicinity and the westerly portion of the New York, New Haven and Hartford Railroad Company, Charles River Branch right of way--would become available for MBTA operations.

System B assumed that:

- Penn Central railroad freight service would be terminated in the vicinity of Wellesley and rail passenger service terminated in Framingham, and that the vacated portion of Penn Central right of way from Framingham to the vicinity of South Station would become available for MBTA operations.

Although the premise for System B was valid, it did not appear realistic at the time of the study to discontinue freight service to the Beacon Park Yards and to railroad-oriented industries in Brighton. Total abandonment of Penn Central operations and services from Wellesley to South Station would be required under System B. The possibility of using the Boston and Maine Railroad freight line through Cambridge to feed the Beacon Park Yards was investigated, and the scheme determined to be physically feasible. With current emphasis

on high-speed ground-transportation systems to serve densely populated centers, however, preservation of a major transportation corridor should be a prime objective. System B was rejected, therefore, and System A was recommended for implementation.

OBJECTIVES

Extensions of rapid transit beyond existing terminals would improve the quality of service for communities outside the Central Area, but only if the extensions were consistent with objectives of the Highway and Transit Master Plan for the Region and the Metropolitan Area.

The Western Corridor commuter has many alternative modes of travel. Rapid transit would have to offer service, therefore, that was dependable, comfortable, economical, convenient and fast in order to attract patrons.

It is recommended that rapid transit be extended into the Western Corridor beyond the Riverside terminus, and planned so that it could be implemented when:

- Parking demand and access to the terminal stations cannot be properly met;
- Express and suburban bus services become slow and unreliable;
- Commuter railroad service declines to the point that discontinuance appears inevitable;
- Rapid transit is needed to relieve roadway congestion in the corridor;
- Travel to special activity centers--transportation (air and land), employment, shopping, educational, medical and athletic--will support rapid transit and reduce the need for additional highways and parking facilities.

Objectives should be:

- Reduction of travel time for Western Corridor patrons destined for other corridors and the Central Area;
- Realization of Master Plan goals of extending rapid transit and connecting the Western and Northeast Corridors;
- Reduction in the number of double transfers required in the Central Area;

- Easier accessibility to Logan Airport for persons whose trips originate along the Western Corridor;
- Advancement toward a balance between modes of transportation;
- Reduction in noise and air pollution, and preservation of an attractive environment;
- Establishment of realistic goals which could be attained in logical progression as funds become available and the need for further extensions becomes evident.

Short-range improvements should be based on current rapid transit technology, but long-range plans should be flexible enough to accommodate future innovations and developing technology.

While the staged improvements proposed for the Western Corridor are not as well defined as those for the basic CASS, it is recommended that initial steps be taken to provide for the ultimate level of service in this corridor.

System A would be constructed in stages, at an estimated cost of $32,000,000 at 1969 levels for the Framingham extension and $12,500,000 for the Needham extension.

Plans and profiles for the ultimate development are presented in Volume III.

ROUTE DESCRIPTION

The recommended System A routing was based on availability of rights of way for rail rapid transit. The proposed routes would use the now inactive portions of existing railroad right of way in the two sectors.

The route for the Framingham Extension high-speed line would begin east of Dennison's Crossing in Framingham. It would continue along the embankment paralleling the Boston & Albany tracks and passing through the towns of Natick, Wellesley and Weston. East of Route 128 the new rapid transit trackage would leave the railroad embankment and continue southward over the proposed Charles River Bridge to a station at Riverside.

The Needham Extension would begin north of West Street and continue northward parallel to the Penn Central Charles River Branch single-track freight line, crossing the Charles River to Newton. The Needham Extension would tie into the existing Highland Branch at Cooks Junction. See Figure 6-1.

Figure 6-1

WESTERN CORRIDOR—STUDY AREAS AND SYSTEMS

STAGED IMPROVEMENTS - SYSTEM A

In the ultimate stage, System A would provide Western Corridor commuters with high-platform rail rapid transit service from Framingham to the Central Area and Northeast Corridor.

A new two-track transit facility would be constructed parallel to the B & A railroad main line from Framingham to Riverside, where it would join the existing Highland Branch tracks. The route then would continue along these tracks and would connect with the Blue Line via System II described in the original CASS report. (See Chapter 4 of this report for systems description.)

At that stage, an evaluation of the type of service to be provided on the Needham Extension would be made to determine whether the existing transit facilities should be converted for high-platform or shuttle operations between Needham Heights and Cooks Junction.

Figure 6-2

SYSTEM A

STAGE 1 PROPOSALS

1. Acquire the unused portion of the Penn Central Charles River Branch (formerly the NY, NH & H RR) right of way that extends from Needham Heights north of West Street to Cooks Junction on the Highland Branch. Build two-track transit from Needham Heights to Cooks Junction.

2. Construct grade-separation structures at Chestnut, Gould and Webster Streets and at Route 128. Build a new Charles River bridge and reconstruct Hunnewell Street overpass.

3. Construct two low-platform stations, at Newton Upper Falls and Needham Heights. At Needham Heights construct a one-track overnight storage facility.

4. Acquire No. 6 cars, and begin service from Needham Heights to the CBD via the improved Highland Branch and Central Subway.

5. Acquire the unused two-track portion of Penn Central (formerly the B & A RR) right of way that extends from Framingham to the Riverside terminal vicinity.

6. Acquire the portion of Penn Central (formerly the B & A RR, Newton Highland Branch) right of way that extends from the Penn Central main line to Route 128.

DESCRIPTION OF STAGE 1 IMPROVEMENTS

Framingham Extension

In Stage 1, no construction is contemplated on the Framingham Extension. Acquisition of all rights of way easement requirements, and lease and option agreements for the future extensions proposed in this corridor is recommended.

Needham Extension

The westerly portion of existing railroad right of way would be acquired and a new double-track transit rail line would be constructed for No. 6 car operations. The tracks would be built to a minimum 55-mile per hour alignment, generally 17 feet west and parallel to the existing track. The proposed 2.5-mile alignment from West Street to Cooks Junction would be located entirely within the existing 81-foot wide Penn Central right of way. This alignment was selected in order to minimize the freight track relocation as well as with interference with the operations of the freight track serving Needham Industrial Park. Subject to agreement among the railroad, the agency, and the towns, in the final planning stage it is recommended that the existing available right of way be wholly redeveloped as a unified transportation corridor designed to benefit both rapid transit and freight operations. (See Alternative Studies.)

The existing right of way is adequate for shared but independent use by the proposed double-track rail transit and the single-track freight line.

Track and Roadbed

Because the existing roadbed was constructed as a single-track section, continuous excavation, embankment and toe of slope retaining wall along the west right of way line would be required. Rock excavation would be necessary between the Charles River and Oak Street, and south of Cooks Junction.

The new track would be built to AREA standards using 115-pound continuous welded rail placed on concrete ties. See Figure 3-2. A minimum of 12 inches of ballast would be placed on the new subgrade. Tracks would be surfaced and aligned.

For overnight storage of eight No. 6 cars at Needham Heights, a one-track siding with a diamond crossover in front of the terminal station would be built to allow trains to enter on the unoccupied side of the platform.

From West Street to Avery Street, a distance of about 1,700 feet, the existing freight track would be shifted a maximum of 25 feet to the east

to allow the transit tracks and terminal facilities to be located within the existing right of way. In order to obtain a desirable grade at the station platform and adequate vertical clearances at the reconstructed Hunnewell Street overpass, the transit tracks would be located a maximum of three feet below the existing freight track grade.

Track connection to the existing Highland Branch would be made by installing at-grade crossovers at Cooks Junction. An alternative study to grade separate the two transit lines was made and found to be technically feasible but, due to economic considerations and anticipated headways, the grade separation was not recommended in this stage.

To facilitate vehicle maintenance, a single-track, reverse-movement connection would be constructed between the Needham Extension and the Highland Branch tracks leading to the Riverside Terminal. The existing freight marshalling track south of Cooks Junction would be relocated to the east of the existing freight track.

General Construction

Construction work in this stage would include two new low-platform stations, street and rail grade-separation structures, a river bridge, retaining walls, parking lots, private drives, reestablished access roads to commercial and industrial areas, drainage structures, fencing, public utilities, a power distribution system, substations, signals and communications.

From West Street to a point north of the Charles River, a distance of approximately 6,700 feet, a toe of slope retaining wall would be constructed to an average height of five feet on the westerly side of the proposed transit line. It is assumed that the existing freight track will remain in its present location, thus restricting the right of way available for transit use. However, if the freight tracks could be shifted eastward, extensive use of retaining wall would be eliminated. See Exhibit 131, Volume III.

New structures would be constructed to grade separate the local streets and arterial roads from rapid transit and freight tracks. The Hunnewell Street and the Oak-Chestnut Streets structures would be elevated to carry vehicular traffic over the rail facilities. Webster and Gould Streets would be depressed. In addition, two new transit bridges would be built, one over Route 128 and the other over the Charles River. The existing Oak Street grade crossing would be closed.

Selection of the new Chestnut-Oak Streets alignment was based upon the requirements for good arterial location and design, and the possibility of future bus use.

To achieve the optimum land development, the proposed grade separation would make extensive use of structure. Local street circulation and access to private and commercial areas would be retained but modified.

Continuous chain link fence, including lockable gates, would be erected on both sides of the transit tracks.

No major utility relocations would be required in this segment.

Stations

Two new low-platform stations would be constructed during this stage. They would be located at West Street in Needham and at Newton Upper Falls in Newton. The low-level center platforms would be 220 feet long and a minimum of 22 feet wide. Platform length would accommodate four No. 6 cars. Stations would be constructed to permit future platform extensions. Passenger shelters on the platforms would have radiant heaters, good lighting and a high degree of visibility for surveillance.

Access to the Needham Heights Station platform would be gained from West Street and access to the Newton Upper Falls Station from the Oak-Chestnut Streets bridge. Fares would be collected either on board the cars or at the agent's booth in the station. Parking lots would be paved and well lighted.

Needham Heights Station

Selection of the site was based mainly on historical precedents. This indicated that the existing land use development was influenced by the location of the railroad station and by access to arterial and local streets which could permit good bus circulation. This station would be located north of West Street.

Passengers would enter the lobby from the West Street sidewalk, pay their fares, and proceed down a short stairway to one end of the center platform. Buses would discharge and receive passengers from an exclusive bus lane on the east side of the station in the Avery Square area. A canopy and a shelter with radiant heaters would protect waiting passengers during inclement weather. Kiss 'n' ride patrons would use a loop inside the parking lot to approach the lobby. A 200-car parking lot would serve the park 'n' ride transit users. Vehicular traffic within the station area would be channeled to minimize interference with street traffic.

Newton Upper Falls Station

This station would be located 1.3 miles north of proposed Needham Heights Station and would have direct access from the proposed Oak-

Chestnut Streets overpass. Selection of the site, to serve both industrial and residential districts and provide arterial street access, was based on information in the following abstracts from the Newton Planning District Analysis - 1967 Report:

> "The New York, New Haven and Hartford Railroad right of way creates a natural boundary line between Subdistricts 17A and 17B.
>
> "The 1960 population of the whole district was 6,917--3,100 in 17A and 3,817 in 17B. The total land area of Planning District 17 amounts to 899.9 acres, with 17B containing the bulk of 624.5 acres. As previously noted, only Planning Districts 2, 4, 5, 6 and 11 exceed the gross density of the former subdistrict.
>
> "This district (17) contains the largest number of (housing) units of any of the planning districts.
>
> "The industrial area is the Needham Street or 'miracle mile' area in which old and new buildings, research and development, and some heavy industry, and a small scattering of commercial uses including a bank, restaurants and others coexist.
>
> "A total of 653 acres of manufacturing zoned land was noted in 17B. Most of this acreage is located in the southwestern portion of the district near the Charles River and the railroad right of way.
>
> "Oak Street serves as the major means of communication between the subdistricts."

The station building would be located adjacent to the bridge over the tracks. Passengers would enter the lobby from the sidewalk on the bridge, pay fare, and proceed down a stairway or reversible escalator to the end of a center platform.

A bus loading dock on the north side of the Chestnut-Oak Streets bridge also could be used by kiss 'n' ride passengers. This facility would be capable of handling possible future crosstown buses as well as mini buses serving the industrial areas.

Parking lots would be constructed on both sides of the proposed facility to accommodate a total of 200 cars.

Because of existing zoning and industrial park development in the combined Newton-Needham area, this station would serve the largest concentrated employment complex in the Western Corridor.

Traction Power

Since the Needham Extension would be interconnected with the Highland Branch, design criteria for the DC Traction Power System would be the same as those used for the Riverside Line study. This extension also would have a 690-450 voltage range, which would supply a no-load bus voltage of 690, a full load bus voltage of 650, and a minimum allowable train voltage of 450.

The simple catenary power distribution system installed in Stage 1 for the Highland Branch would be extended from Cooks Junction to Needham Heights.

A new substation containing two 1,500 kw rectifier units would be built at Needham Heights.

Signals and Communications

The multispeed signal system with overspeed control and communications systems, described under Stage 1 of the basic CASS (see Chapter 3 of this report), would be extended from Cooks Junction to Needham Heights. An automatic train dispatcher would be installed at Needham Heights Station.

New interlockings would be installed at Needham Heights, Newton Upper Falls and Cooks Junction.

Rolling Stock and Operations

A fleet of new No. 6 cars would be placed in service between Needham Heights and the Central Area. If this service should be initiated prior to the implementation of the proposed Orange Line extension and if rail commuter service should continue to decline, it may be desirable to evaluate the use of A and B (skip-stop) service on the combined portion of the Riverside-Needham Heights Line.

Vehicle Support Facilities

Storage space would be provided for eight No. 6 cars along the west side of the proposed transit line in the vicinity of the Hunnewell Street bridge. Additional storage space would be available in the Needham Heights Station area. There would be no service facilities at this location.

Maintenance, inspection and repair of the new No. 6 cars on the Needham Extension would be performed at the Riverside Shops built under Stage 1 of basic CASS. To facilitate the movement of vehicles scheduled for maintenance, a single-track connection for two-way

movements would be built at Cooks Junction between the Needham Extension and Highland Branch.

DESCRIPTION OF STAGE 2 IMPROVEMENTS

Framingham Extension

Track and Roadbed

The former B&A right of way from Framingham to South Station contained four tracks. Construction of the Boston Extension of the Massachusetts Turnpike required elimination of the two northern tracks between Riverside and the vicinity of South Station. Subsequently, the two southern tracks (Numbers 3 and 4) were removed between Framingham and the vicinity of the present Riverside terminal.

The continued presence of the unused portion of the two-track right of way west of the Riverside terminal makes the location of the proposed rapid transit extension attractive and feasible.

The proposed MBTA tracks would be constructed parallel to and south of the existing main line track. The distance between adjacent transit and railroad tracks would be 17 feet. East of the Route 128 collector-distributor road, the tracks would leave the existing railroad embankment on a 600-foot radius curve and connect with the new Riverside Station via the proposed Charles River crossing.

The existing railroad roadbed would be widened and regraded to accommodate the additional clearances required between the electrified transit and railroad operations. In general, the profile of the proposed transit tracks would be located one foot above the existing railroad tracks in cut areas and one foot below the existing railroad tracks in embankment areas. This arrangement is recommended in order to minimize the height of retaining walls and reduce private property takings. The new track would be built to AREA standards with continuous welded 115-pound rail on concrete ties, placed on new ballast. The track alignment would conform to MBTA requirements for curvature and superelevation for 65-mile-per-hour operation. In Framingham, east of Dennison's crossing, two storage tracks would be constructed for 26 No. 5 Red Line-type cars. A non revenue, grade-separated track connection would be built between the Framingham Extension and Riverside Yard. See Exhibit 84, Volume III. Emergency crossovers would be installed east of every rapid transit station.

General Construction

Construction work in this stage would include new high-platform stations; car storage and minimum maintenance facilities at East

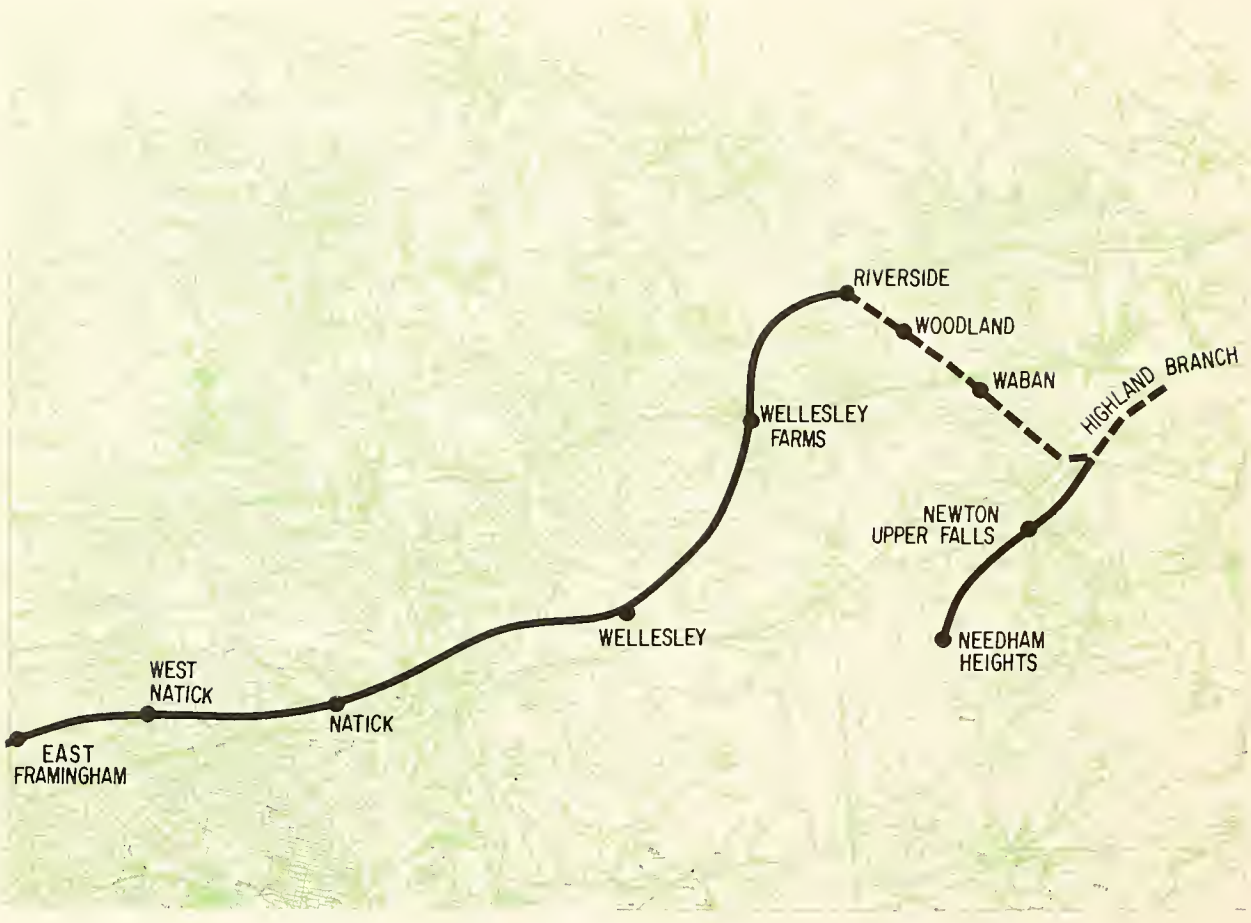


Figure 6-3

SYSTEM A
STAGE 2 PROPOSALS

1. Reconstruct most of the bridges from Framingham to Riverside.

2. Extend Highland Branch tracks over the previously acquired B & A Railroad right of way from the Riverside terminal to Framingham. If the proposed extension to Wellesley Farms is not completed, see Alternative Studies.

3. Construct new high-platform stations at Wellesley Farms, Wellesley, Natick, West Natick and East Framingham.

4. Construct a storage, service and inspection facility at the proposed terminal in Framingham.

5. Acquire Blue Line-type rapid transit cars for Western Corridor operations.

6. Initiate high-platform service from Framingham to the downtown area via the upgraded Highland Branch, and operate A and B (skip-stop) service from Riverside to the Central Area.

7. Evaluate the need for high-platform or shuttle service from Needham Heights to Cooks Junction.

Framingham; bridge structures, parking lots, and transfer facilities; and retaining walls and extensions of drainage structures.

Twenty-one bridges would be built or reconstructed to the No. 5 Red Line car clearance standards of MBTA for rapid transit operation. Bridges would have to be reconstructed in compliance with MBTA horizontal clearance standards, and existing Penn Central tracks would have to remain in their present location. Two of the existing bridges meet these requirements.

MBTA standards for horizontal clearance call for a minimum of 38'-6" between center line of the nearest existing railroad track and the face of the existing abutment adjacent to the proposed transit tracks. On six of the existing bridges to be reconstructed, this dimension is between 38'-6" and 35'-6"; on nine bridges it is between 35'-6" and 32'-0". Four existing bridges carrying rail traffic would have to be modified to accommodate two transit tracks on widened track centers.

A new double-track bridge about 500 feet long would have to be built across the Charles River west of the Riverside Station. In addition, a double-track bridge 150 feet long would be needed over existing Route 128.

Retaining walls would have to be built to comply with minimum clearance standards between existing railroad tracks and proposed transit tracks without encroaching on adjacent property.

Stations

Factors influencing siting of new transit stations in the Western Corridor were:

a. Availability of inexpensive land for all-day parking lots.

b. Accessibility via arterial streets.

c. Proximity to communities and new middle-income housing developments that would generate patronage for rapid transit service.

d. Availability of railroad property such as existing railroad station sites and parking lots, and access facilities serving them.

Five new stations would be built between Framingham and Riverside: East Framingham, West Natick, Natick, Wellesley and Wellesley Farms. Each station would have a 300-foot center platform with

a canopy, and would be extendable to 440 feet. Fare collection lobbies would be above the tracks. Both stairs and reversible escalators would be installed. Volume III of this report contains plans of these stations.

The East Framingham Station would lie east of Dennison's Crossing. The terminal facilities for the Framingham Extension would consist of an end-loaded center platform with access to the station from both sides of the tracks. Transit car maintenance facilities would comprise minor inspection and repair facilities only. A 440-car parking lot would be built south of the proposed station.

Although such a station would serve a growing area of Framingham, a site nearer the center of the Town of Framingham would be better. Proposals for grade separations and changes in street traffic patterns, however, have not been agreed to between officials of the Commonwealth and the Town. Numerous studies were made for in-town stations and East Framingham was selected as the best place for the transit terminal.

The West Natick Station would be about 1.5 miles east of the proposed East Framingham Station. Speen Street would be the major north-south arterial roadway serving this station, and could be used by feeder buses. Adjacent property now being used by the Massachusetts National Guard and owned by the Commonwealth might be obtained for a parking lot for 275 cars, bus access roads, and kiss 'n' ride facilities. Access to the center-loaded platform would be from the north via a new pedestrian bridge over existing railroad tracks.

Natick Station would be in the center of the Town of Natick immediately east of the Washington Street bridge. The area over the tracks for about 1000 feet east of Washington Street would be decked to create parking space for 400 cars. A station lobby on this deck would serve the end-loaded platform below. Present plans of the Town of Natick envision building a new Penn-Central commuter railroad station about 3500 feet west of Washington Street and constructing adequate parking facilities for commuters. Implementation of Town plans would require reconsideration of plans for the transit station.

Wellesley Station would be in the heart of town near the existing railroad commuter station, and approximately three miles from Natick Station. Park 'n' ride patrons would use existing parking facilities several hundred feet west of the station. Station siting would be compatible with the Town of Wellesley's "Comprehensive Plan of 1965." A new street north of the station and parallel to the tracks connecting Hollis and Everett Streets would be used by kiss 'n' ride patrons and as a bus access roadway. Passenger access to the station lobby over the tracks would be from both sides of the tracks via reversible escalators and a passageway over existing railroad tracks.

Wellesley Farms Station would be about two miles southwest of Riverside Station, between Glen Road and Woodlawn Avenue. Of the various transit station sites suggested in the Comprehensive Plan, this one was selected for its superior accessibility from Weston and other adjacent communities and for its existing and potential parking facilities. Bus users and kiss 'n' ride patrons would enter the station lobby over the tracks off Hundreds Road which would flank the west side of the station. Parking lots for an additional 400 cars would be built east of the tracks.

Continuous chain link fence would be constructed along both sides of the transit tracks, separating railroad from transit facilities along the north side and coinciding with the right of way line on the south side.

Drainage structures would be extended where required, but no major utility relocations would be necessary.

Traction Power

Since the Framingham Extension would be connected with the Highland Branch, design criteria for the DC traction power system for this line would be the same as those used for the Riverside Line study. This extension also would have a 690-450 voltage range, which would supply a no-load bus voltage of 690, a full-load bus voltage of 650, and a minimum allowable train voltage of 450.

The simple catenary power distribution system installed in Stage 1 for the Highland Branch would be extended from Riverside Station to East Framingham Station.

New substations would be built at Lower Falls, Wellesley Hills, Morse's Pond, Fisk Pond and East Framingham. Each new substation would be equipped with two 1000-kw rectifier units. Sites for new substations are shown on Exhibit 135 in Volume III of this report. while substation requirements are given in Appendix E.

Signals and Communications

The multi-speed signal system with overspeed control and communications systems described in Chapter 3 of this report would be extended from the Riverside terminal to East Framingham. An automatic train dispatcher would be installed at East Framingham terminal station.

New interlockings would be installed at East Framingham, West Natick, Natick, Wellesley, Wellesley Farms and Riverside.

Rolling Stock and Operations

A fleet of new cars, similar to the Blue Line cars, would be acquired and placed in service between East Framingham and the Central Area or on to the Northeast Corridor.

It is recommended that skip-stop service be instituted only between the Riverside and Back Bay Stations.

Vehicle Support Facilities

Storage space would be provided for 26 No. 5 Red Line-type cars along the south side of the existing Penn Central tracks west of the proposed East Framingham Station. The two storage tracks would terminate just east of Dennison's crossing. A shop for minor inspection and repairs would be built for cars on the Framingham Extension. Major repairs and maintenance of the new high-platform vehicles on the Framingham Extension would be performed at the Riverside shops built under the immediate action improvement program. See Chapter 3 of this report. A grade-separated track connection would be constructed between the Framingham Extension and Riverside Yard to facilitate movement of vehicles bound for the shops to receive daily maintenance services.

SYSTEM B

Items of Work to be Performed

1. Acquire the currently unused two-track portion of the right of way and the existing southerly track of the B & A between East Framingham and Wellesley.

2. Acquire the entire existing right of way including two tracks between Wellesley and South Station.

3. Between East Framingham and Wellesley, shift the southerly track southward to clear the remaining freight track by 17 feet. Construct one additional track south of the relocated track. These two tracks would be used for MBTA transit operations.

4. Assuming termination of freight service east of Wellesley, connect transit tracks to existing railroad tracks. Weld all rails to be used in transit operations.

5. Construct a new two-track connection from Framingham Extension to Riverside yard, and eastward

from the Riverside yard to the former railroad tracks.

6. Construct new high-platform stations at East Framingham, West Natick, Natick, Wellesley, Wellesley Farms, Riverside (unless built previously), West Newton, Newtonville, and Brighton. Construct a two-level station with a grade separation at Fenway Park.

7. Construct overnight storage tracks and a shop for minor inspections and repairs at the East Framingham terminal.

8. Electrify and signalize the rapid transit route, and fence MBTA right of way.

9. Modify Riverside shops for high-platform cars and build the new yard, unless this work had been done previously.

10. Acquire a fleet of new high-platform cars.

11. Initiate service from East Framingham and from Riverside to the Central Area and the Northeast Corridor, using skip-stop operation between Riverside and Back Bay Stations via the B & A.

12. Operate high-platform rapid transit service from Needham Heights to the Central Area via the Highland Branch and from Riverside if demand warrants.

Construction Requirements

The new track to be built between East Framingham and Wellesley would be constructed of continuously-welded 115-pound rail and concrete ties on new ballast. Rails of the existing track to be used for transit would be welded into long lengths. The track would be moved about five feet south onto existing ballast after it had been cleaned for reuse.

East of Wellesley, the two transit tracks would be connected to two existing railroad tracks to form a continuous transit route from East Framingham to South Station. Existing rails would be welded, tracks aligned and surfaced, and worn ties--about one-third of the total--would be replaced. At Riverside, two double-track connections to the Highland Branch would be built for train movements to the east and to the west. Emergency crossovers would be installed on the downtown

side of all transit stations. The entire MBTA right of way would be fenced.

All existing bridges would have sufficient horizontal clearances for two transit tracks and one freight track from East Framingham to Wellesley, and for two transit tracks from Wellesley to South Station. A new bridge across the Charles River near Riverside Yard would be necessary if main line transit service were to be routed via the Highland Branch as in System A.

Construction of retaining walls and lengthening of existing drainage structures would be required only in the vicinity of stations. Stations on the Framingham Extension would be built as described in System A. Additional transit stations would be built at West Newton, Newtonville and Brighton.

The stations at West Newton and Newtonville would have fare collection lobbies over the tracks. The Brighton station lobby would be in the railroad embankment under existing tracks. It would be served by an adjacent bus terminal and a kiss'n ride lane.

Among bus routes serving this terminal would be those originating in Watertown. Patrons from Watertown would be able to reach the Central Area faster, and street traffic in the Kenmore Square area would be reduced.

Transit riders would be attracted from surrounding communities by a 200-space parking lot at West Newton Station and a 250-car lot at Newtonville Station as well as by feeder bus and kiss'n ride facilities at both stations.

Since this Extension would be connected to the Highland Branch, a simple catenary power distribution system including four new substations at West Newton, Newton, North Brighton and Fenway Park (if not previously built) would be constructed. Each new substation would be equipped with two 1500-kw rectifier units.

Locations of new substations are shown on Exhibit 136 in Volume III of this report, while substation design criteria are given in Appendix E.

The signal and communications systems described in Chapter 3 would also be installed on this route. New interlockings and dispatchers would be installed using the design criteria outlined in Chapter 3.

A new fleet of high-platform transit cars would be acquired and placed in service between East Framingham and the Central Area or on to the Northeast Corridor.

It is recommended that skip-stop service be rendered between the Riverside and Back Bay Stations.

Vehicle support facilities described in this Chapter for System A would also apply to System B.

WESTERN CORRIDOR ALTERNATIVES

Riverside to Middle Circumferential Expressway

The "Recommended Highway and Transit Plan" published by the Massachusetts Department of Public Works in January 1969, recommended that the Riverside Line be converted to high-platform rapid transit operation and extended from Riverside Station to the new Middle Circumferential Expressway near the Wellesley-Natick line.

To date, no alignment or even a corridor has been established for the proposed Middle Circumferential Expressway and it is not the intent of this report to indicate or infer any expressway location. A possible location for a transit terminal station was investigated, however, on the basis of minimum land requirements and technical feasibility.

The station site studied is 1.5 to 2.0 miles west of the proposed Wellesley Station in an area between University Drive in Natick and Pond Road in Wellesley. Within these limits the railroad right of way is only about 80 feet wide. The land adjacent to the railroad is occupied by middle-to-high income single-family houses and estates; thus, obtaining large parcels of land for a 4,000-car parking lot and suitable terminal facilities would conflict with the Town of Wellesley's policies of protecting such residential areas. Until the final alignment or corridor for the Middle Circumferential Expressway is known, it is recommended that no further consideration be given to a station in this area.

Riverside to Framingham

In order to conform with minimum MBTA horizontal clearance requirements for the proposed two-track transit facility, a dimension of 38'-6" from center line of existing southerly railroad track to southerly bridge abutments was used to design and estimate the cost of the Framingham Extension-System A. Under this criterion, most of the existing bridges would have to be reconstructed.

If an agreement between the railroad and the Authority were reached to accept lower horizontal clearances between the operating railroad and electrified transit, the cost of retaining walls and bridge reconstruction would be greatly reduced.

A dimensional inventory of bridges on the Framingham Extension follows:

	Existing Clearances	Proposed Clearances		
	℄ Existing Southerly RR Track to Southerly Abutment	℄ Existing RR Track to ℄ Transit Track	℄ to ℄ Between Transit Tracks	From ℄ Transit Track to Obstruction
		(all in feet)		
Route 128 (Collector-Distributor Rd.)	36.3 (O)	15.0	13.0	8.3
Park Rd.	32.0 (O)	13.0	13.0	6.0
Intervale Rd.	32.3 (O)	13.0	13.0	6.2
Glen Rd.	32.3 (U)	13.0	13.0	6.3
Woodlawn Ave.	34.6 (U)	15.0	13.0	6.6
State Route 9	33.3 (U)	13.0	13.0	7.3
Cliff Rd.	37.9 (U)	17.0	13.0	7.9
Rockland St.	34.3 (U)	15.0	13.0	6.3
Kingsbury St.	32.5 (U)	13.0	13.0	6.5
Crest Rd.	36.1 (U)	15.0	13.0	8.1
Weston Rd.	38.8 (U)	17.0	13.0	8.8
Bacon St.	$30^{\pm}$ (O)	13.0	13.0	$4.0^{\pm}$
Marion St.	35.8 (U)	15.0	13.0	7.8
Washington St.	36.6 (U)	17.0	13.0	6.6
Walnut St.	36.7 (U)	17.0	13.0	6.7
Main St.	36.7 (U)	17.0	13.0	6.6
Washington Ave.	33.0 (U)	13.0	13.0	7.0
Spear St.	33.3 (U)	13.0	13.0	7.3
Mill St.	33.3 (U)	13.0	13.0	7.3
Boden Lane	32.6 (U)	13.0	13.0	6.6

(O) Transit Over
(U) Transit Under

It would be desirable to improve grade separation structures to minimum horizontal clearance criteria. To reduce total construction costs, however, it is recommended that only bridges which fall below absolute minimum standards (15.0 feet from the center line of the existing southerly railroad track to the center line of the proposed northerly transit track) be rebuilt. If this standard were adopted, only ten bridges would have to be changed for two-track transit and two-track railroad operations.

This recommendation applies only to the interim program. When an overall grade separation improvement program is instituted, the standard criteria should be observed.

Two new double-track bridges, one over the Charles River and the other over Route 128, would be built west of Riverside Station.

Riverside to Wellesley Farms

Traffic projections show that ridership west of Reservoir Station would be increased 85 percent during the next 20 years by implementing Stage 1 and expanding parking lots. However, if System II were implemented and parking demands met, patronage would increase by 360 percent.

ESTIMATED NUMBER OF INBOUND PASSENGERS BY ORIGINATING STATION SHOWING PARKING SPACE DEMANDS FOR VARIOUS SYSTEMS, EXTENSIONS AND IMPROVEMENTS

Stations	(1) Existing (1970)		STAGE 1 (1990) *(Alternative 5)		(2) SYSTEM I (1990) (Alternative 1)		(3) SYSTEM A (Western Corr.) (1990) SYSTEM II (Basic CASS) (1990) (Alternatives 2, 3)	
	Orig. Pass.	Parking Spaces	Orig. Pass.	Parking Spaces	Orig. Pass.	Parking Spaces	Orig. Pass.	Parking Spaces
Framingham							2,990	1,150
Speen Street							1,320	500
Natick Middle Belt							3,100	920
Wellesley							710	160
Wellesley Hills							1,020	170
Wellesley Farms							830	220
Riverside	2,300	1,617	6,200	4,864	12,074	7,385	8,870	5,300
Woodland	970	351	1,780	308	5,294	2,113	710	150
Waban	540	47	1,065	89	1,026	204	1,080	210
Eliot	450	67	720	158	---		---	
Newton Highlands	955	0	1,430	19	2,761	810	2,460	770
Newton Center	2,060	0	2,270	12	4,499	1,005	4,360	1,070
Chestnut Hill	730	67	1,280	208	3,193	1,036	3,040	1,190
TOTAL	8,005	2,149	14,745	5,658	28,847	12,553	30,500	11,800

* - For definition of Alternatives see Volume I of this report.

(1) Originating passengers 1970 include trips in both directions from each station; 1990 forecasts include inbound trips only.

(2) System I includes express feeder bus service to Riverside.

(3) The number of 24-hour inbound originating passengers and parking demands by station for System A (Western Corridor) were not produced by the Authority. Numbers shown were developed by dividing total 24-hour inbound originating passengers by peak period inbound station boarding total and multiplying individual peak period originating passengers and parking demands by station by the factor $\frac{49,620}{20,473} = 2.4$):

The above figures were used only to compare parking space demands for systems, extensions and improvements west of Reservoir Station.

Any of the alternatives studied, including Stage 1 improvements, would produce park 'n ride demands well above existing capacities of parking lots. The supporting highway network and access roads could not handle the projected peak hour traffic, moreover, even if parking lots were expanded or parking structures built. Construction of a parking garage over the Riverside Yards, therefore, is not recommended. Instead, extension beyond Riverside should be considered so that the needed parking capacity could be attained.

Preliminary studies indicated that a site north of the existing Penn Central tracks bounded by Park Road, Riverside Road and Route 128 in Weston would be satisfactory for such an initial extension. However, a new office complex known as Riverside Park is being developed on this site. The first of five 54,000-square-foot buildings in this park has already been dedicated. The area opposite this site south of the railroad is presently occupied by a public golf course.

These two developments appear to preclude station facilities and a supporting parking lot in this area. Farther west the topography and the curvilinear alignment of the tracks make an extension in Weston appear unlikely.

The next possible location investigated was the Wellesley Farms area. The station would be accessible via Glenn Road from the Wellesley Farms area and Weston as well as via good local streets from Wellesley Hills. The town now has potential park 'n ride facilities for 250 cars with expansion for another 400 to 650 cars feasible. Local streets on both sides of the station would provide excellent kiss 'n ride and feeder bus pickup and discharge points.

The station, parking lots, tracks, traction power distribution, signals and communication systems would be designed and built on the basis of the design criteria previously described in this chapter for Framingham Extension - System A. A diamond crossover for turnback operations would be installed west of the proposed Wellesley Farms Station.

The proposed extension would be terminated approximately two miles southwest of the proposed Riverside Station which would be east of the existing Woodlawn bridge. The station and parking facilities would be compatible with the ultimate Framingham Extension--System A proposals. See Exhibit 81, Volume III of this report.

It is recommended as a short-range plan that the Highland Branch be extended beyond the Riverside area to the Wellesley Farms area. This would reduce demand for parking space west of the Reservoir Station. The cost of this extension at 1970 levels would be approximately $5,000,000.

Systems A and B Alternatives

Many alternate concepts involving the use of portions of the Penn Central's (formerly B & A Railroad) existing facilities were considered and were further investigated as to cost, functional adequacy and operations.

As alternatives to both Systems A and B, consideration was given to the possibility that commuter railroad operations in this corridor might be discontinued. In this event, it was assumed that the Penn Central would retain single-track freight service from Framingham to at least the Beacon Park Yards and possibly to South Station. From Framingham to Riverside, curtailment of railroad operations to one of the existing tracks would permit development of an attractive two-track transit facility since it would make unnecessary most of the retaining walls and bridge reconstruction on the Framingham Extension. In addition, a single-track, high-speed rail rapid transit operation could be instituted from the vicinity of Riverside to Fenway Park, Back Bay or South Station, thus providing both express and local service. Under this concept, local trains would cross the new two-track Charles River bridge and continue to the downtown area via the Highland Branch. Express trains would continue easterly on a single-track facility south of the existing Penn Central freight track. The desirability of grade separating the express route from the Riverside Line local line west of the Riverside Station could not be evaluated at this time due to lack of traffic data.

Express transit trains operating parallel to the Penn Central could be turned back via the Highland Branch or, depending on headway requirements, could be returned via the single track line. The closest headway that could be operated between Riverside and Back Bay, using the single track line, would be about 30 minutes. For running times between Framingham and the Central Area see Figure 6-4. Such a plan would offer both through and local passenger service direct to downtown without a transfer. Cross-platform transfers would be available, nevertheless, on the Framingham Extension, at Back Bay Station and perhaps at other stations. Passengers originating in Newton and nearby communities could be offered fast and frequent service in both peak periods. In off-peak periods, service could operate in both directions over the single track.

Needham Heights to Needham Junction

An in-depth study was made of ways to extend the Needham Extension from West Street in Needham Heights to Needham Junction. One potential alignment of a rail transit extension would meet all design criteria. However, the vertical profile would present many problems. The spacing and number of present at-grade crossings in this section would necessitate placing tracks on elevated structure or in subway for the entire length of the extension. Thus Needham Heights and Needham Center Stations would be in tunnel or on elevated structure. Needham Junction Station would be on the existing railroad embankment opposite Grant Street.

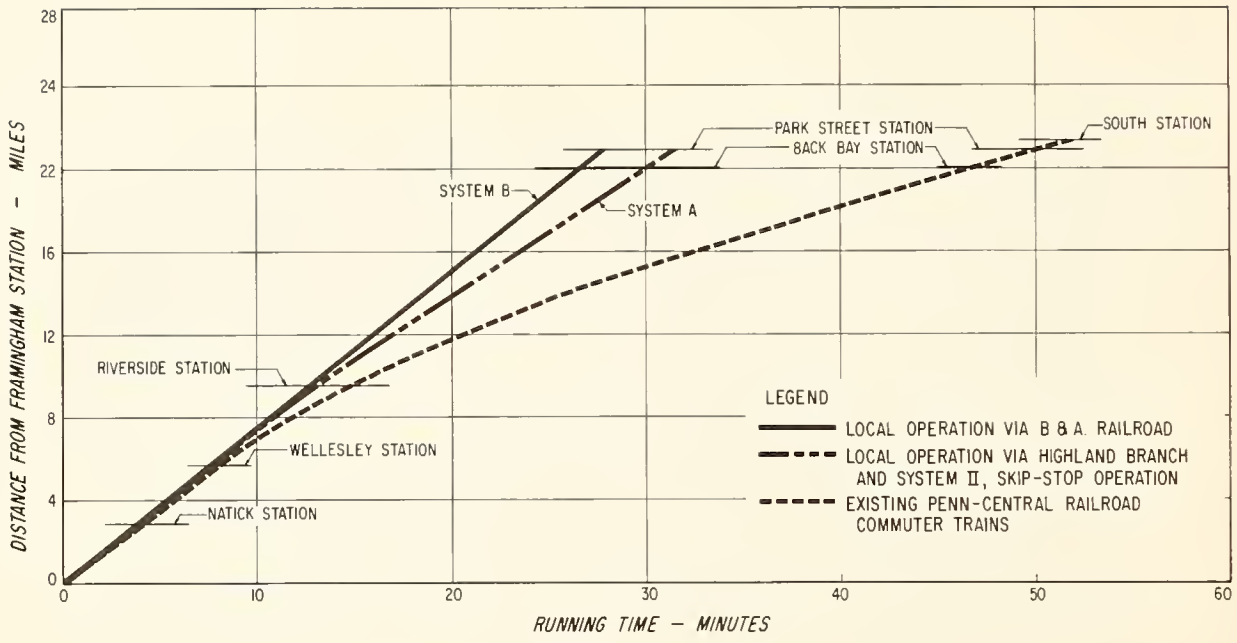


Figure 6-4

RUNNING TIMES BETWEEN FRAMINGHAM AND CENTRAL AREA

The existing single-track freight line would be grade-separated where it crossed the transit tracks near Oak Street, but it would operate on existing alignment west of Maple Terrace. Structures to grade-separate the freight track from local roads, (Great Plain Avenue, May Street, Rosemary Street and West Street) were not studied or included in the cost estimates.

The cost of this 9,000-foot extension would be approximately $38,722,000 which is considered excessive considering the value of the service it would permit. Extending the line beyond Needham Heights is not recommended, therefore, because of the extremely high cost and the possibility that the Orange Line might be extended to serve the Needham Junction area.

BENEFITS AND LIMITATIONS

Traffic

As mentioned earlier, the potential growth of transit ridership in the Western Corridor would generate approximately 20,000 additional inbound trips per day by 1990, most trips starting west of Reservoir Station. This would represent a 360 percent increase over patronage on the existing system. Stage 1 improvements would produce only an 85 percent increase in patronage.

NUMBER OF PASSENGERS ORIGINATING IN THE WESTERN CORRIDOR

Present System in 1970; Stage 1 in 1975 and 1990; and System I and System A - System I in 1990

Stations	Existing System 1970	Stage 1 1975	Stage 1 1990	System I 1990	System A-(Western Corridor) System I 1990
Framingham				(3)	2,990
Speen Street					1,320
Natick Middle Belt					3,100
Wellesley					710
Wellesley Hills					1,020
Wellesley Farms	(1)	(2)			830
Riverside	2,300	3,315	6,200	12,074	3,870
Woodland	970	1,580	1,780	5,294	710
Waban	540	855	1,065	1,026	1,080
Eliot	450	595	720	--	--
Newton Highlands	955	1,133	1,430	1,761	1,460
Newton Center	2,060	1,685	2,270	4,499	4,360
Chestnut Hill	730	810	1,280	3,193	2,040
Subtotals(Inbound Originating Passengers West of Reservoir)	8,005	9,973	14,745	28,847	30,500
					(4)
Reservoir	1,330	1,334	1,283	6,461	6,461
Beaconsfield	375	420	469	--	--
Brookline Hills	1,665	1,635	1,521	2,333	2,333
Brookline Village	2,030	1,995	1,398	3,469	3,469
Longwood	1,160	1,130	462	1,339	1,339
Fenway	2,600	3,775	3,048	3,369	3,369
Subtotals	17,255	20,262	22,206	45,818	47,471
Beacon Line Portal	11,000	7,097	7,395	2,358	2,358
Commonwealth Line Portal	14,200	10,810	10,465	5,613	5,613
Totals at Kenmore Station	42,455	38,169	40,066	53,789	54,442

Notes:

(1) 1970 and 1975 figures include both inbound and outbound trips.

(2) 1990 forecasts include inbound trips only.

(3) Figures developed from a 24-hour to peak-period factor.

(4) Number of passengers originating east of Chestnut Hill Station assumed to be the same as for System 1.

(5) Number of originating passengers for System II are similar to those for System I.

The foregoing table shows that a potentially good market exists for rail transit service beyond the Riverside terminus, assuming conversion of the Riverside Line to high platform operation.

Traffic analyses indicate that an extension to the Wellesley-Natick-Framingham area would not produce a substantial net increase in transit trips in comparison with System I (Riverside Line converted to high-platform operation and connected to the Blue Line). It would be unrealistic, however, to assume that the demand for 12,550 parking spaces could be met west of Reservoir Station for the System I concept.

Even Stage 1 improvements would not produce the projected transit ridership growth of 85 percent if the demand for an additional 4,000 parking spaces could not be satisfied west of Reservoir Station. Furthermore, if an extension beyond Riverside were not built, projected increases in ridership might never be realized due to the inadequacy of access highways and parking facilities.

The potential loss of about 10,000 daily inbound transit passengers would represent about $6,000,000 per year in fare box revenue.

10,000 x 2 (two one-way trips) = 20,000 daily passenger trips

300 days x 20,000 = 6,000,000 annual rides

6,000,000 x $1.00 (assumed one-way fare for an entire trip including the extension) = $6,000,000

Additional transit patronage in large volumes would probably be generated by the many multi-unit residential projects planned or under way in the Western Corridor. These include ten-story buildings on Captain Tom's Hill and low-rent apartments near the Natick line in Framingham as well as the 190-acre, 2400-unit development of high-density dwellings in West Natick. A substantial volume of reverse riding should develop between the economically disadvantaged inner areas and such industrial complexes as General Motors, Dennison's Manufacturing, and the Needham and Newton Industrial Parks.

In addition, a potential transit-oriented market exists from the Western Corridor to Logan Airport. This corridor currently generates approximately 3,200 deplaning air passengers daily of which only 190 use transit. If the proposed improvements including the through connection to the Blue Line are made, perhaps 30 percent of the trips from Logan Airport would be made by transit, thus producing an additional 750 trips per day in each direction. Furthermore, the City of Boston is the origin or destination of 25 percent of the trips, most of which start or end in the down-

town area. Only seven percent of the latter trips are presently made by transit. The Prudential and Park Square areas, which are served by the Green Line, account for 38 percent of the total downtown trips. The low transit usage of 2.8 and 4.6 percent, respectively, might be raised substantially if the connection and improvements to the Green Line were implemented.

Potential traffic growth and revenue should not be the only factors considered, however, in evaluating a transit plan. There are other potential benefits which do not lend themselves to economic evaluation but are nonetheless important. Those which have considerable influence on a community's development include:

- Reduction of air and noise pollution.
- Preservation of existing and proposed developments.
- Encouragement of developments in housing, industry and commerce.
- Provision of greater mobility for the young, aged, economically disadvantaged, physically handicapped, and unemployed.
- Improved safety, comfort and dependability for transit users.
- Improved accessibility of areas served, which enhances property values.
- Preservation of ecological balance.

Other direct economic benefits which have not been evaluated in this report include:

- Time savings for transit users.
- Time savings for motorists because of less congestion.
- Time savings for truckers because of less congestion.
- Reduction in capital investment in new or improved streets and highways.
- Savings from termination of present express bus services.

The above lists are incomplete but they indicate the many benefits that contribute to the total value to a community of a modern, adequate rapid transit system.

Corridor Limitations

Systems A and B were developed under the premise that the Penn Central right of way or portions of the right of way would become available for exclusive or shared use by the Massachusetts Bay Transportation Authority for rapid transit operations. System A, System B, and the alternatives investigated would require acquisition of the Penn Central right of way to the following extent:

- System A--Framingham to Riverside Assumed that freight and commuter railroad operations would continue. The unused two-track portion of right of way would be acquired for rapid transit.

- System A Alternative--Framingham to Riverside Assumed that commuter railroad services would be discontinued. Freight operation would be confined to a single track. One track and the unused two-track portion of the right of way would be acquired for rapid transit.

- System A--Needham Heights to Cooks Junction Freight operation would be confined to the existing single track. The westerly portion of the railroad right of way would be acquired for two-track transit operation.

- System B--Framingham to Wellesley Assumed that freight services would be terminated east of Wellesley and that rail commuter services would terminate at Framingham. One track and the unused two-track portion of the right of way would be acquired for rapid transit.

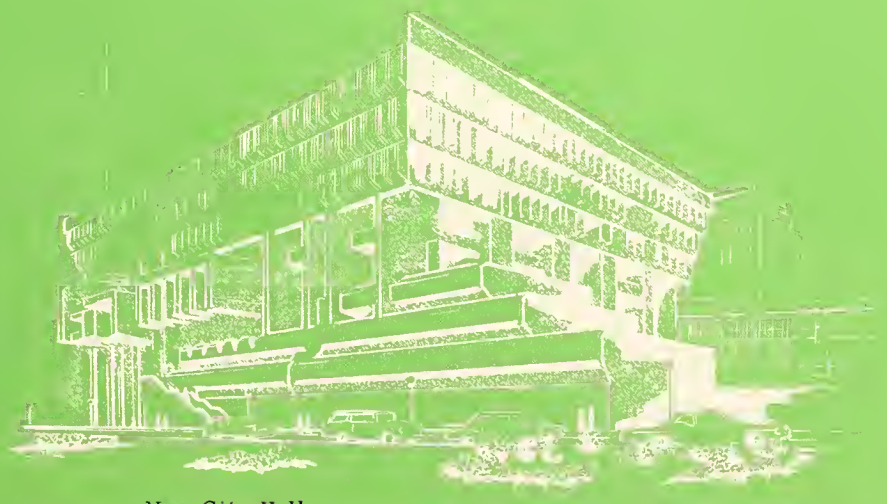
- Wellesley to Back Bay or South Station Assumed that both freight and commuter services would be discontinued. The entire existing railroad right of way would be acquired for rapid transit.

- System B Alternative--Framingham to Back Bay or South Station Assumed that freight service would continue to be operated on a single track.

System B, although valid for this study, would require total abandonment of railroad operation in this corridor. Nevertheless, it is possible that Boston and Maine Corporation facilities could be used for freight service from the west to the Beacon Park Yard. See November 1968, Regional Transportation Needs Report. The New England Regional Commission suggested that serious consideration be given to use of the B&M corridor for interstate passenger and freight movements into the Boston

area. The B&M route through northern Massachusetts is shorter than the Penn Central route by 13 miles and it has many fewer adverse grades. The superiority of this route is shown by the fact that a given locomotive can haul twice as heavy a train eastbound on this route as on the Penn Central. The new electronic classification yards under construction at Selkirk are some 20 miles east of Rotterdam Junction, however, and this will require a backhaul to reach the B&M. The advantage of the more direct line of the B&M, therefore, will be lessened. The Beacon Park Yard could be served from the B&M system, but that would require separation of present grade crossings in Cambridge.

Although System B is not recommended, preservation of this major transportation corridor for high-speed rail transit should be the prime objective in placing these facilities in the land bank for future mass transportation use.



New City Hall

Chapter 7
ESTIMATED CAPITAL COSTS

MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

Chapter 7

ESTIMATED CAPITAL COST

Preliminary cost estimates have been prepared for the Systems and Line extensions described in Chapters 3, 4 and 6.

Each route has been divided into segments that were determined by geographical boundaries, intersections with other routes, or by the method that might be used to construct the proposed facility. Segments are shown on Figures 7-2 through 7-6. The length of each segment was obtained from limits shown on the plans in Volume III of this report.

The major items of work included in this estimate are:

General Construction. This item includes all permanent and temporary structures, earthwork, street work, city-owned utility work, lighting, fencing and mechanical facilities such as fans and pumps.

Track and Roadbed. Included in this item are rail, ties, track fastenings, special work, ballast, drainage and preparation of subgrade.

Traction Power Supply and Distribution. This item includes substations, feeder cables, and overhead and contact rail distribution systems.

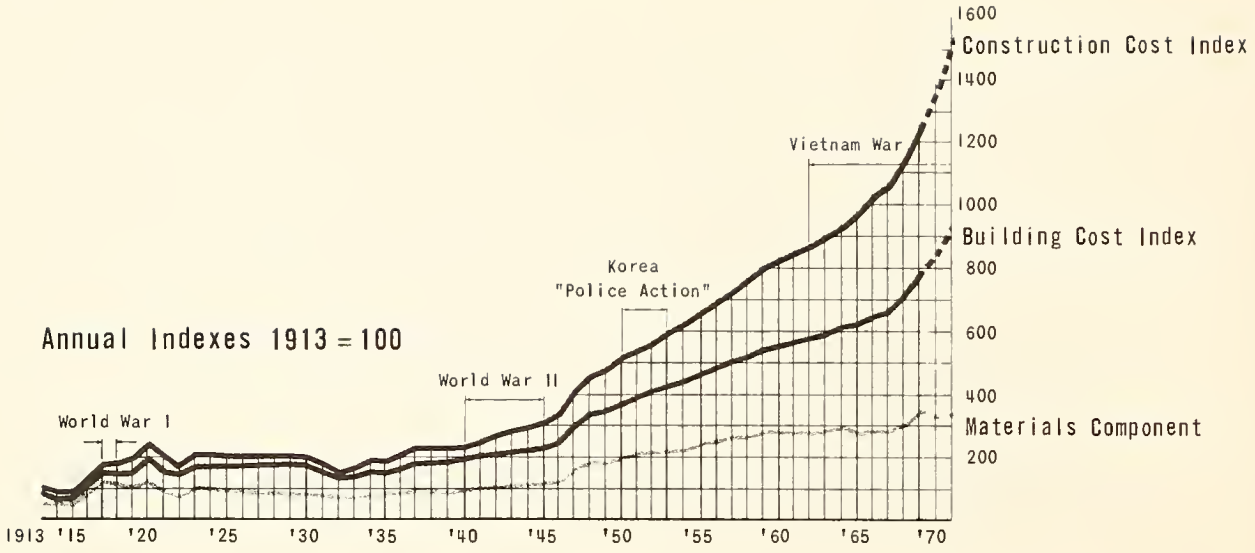
Signals and Interlocking. This item includes the cost of furnishing and installing a new cab signal system, automatic train identification equipment and interlocking plans at junctions.

Communications. Modern two-way radio dispatching, public address systems in cars and stations, and telephone circuits are included here.

Cost items not included in these estimates are:

- Right of way acquisition or building demoliton.
- Civil engineering improvements to surface portions of the Green Lines.
- Rolling stock.
- Maintenance and repair installations at East Framingham, Riverside and Reservoir.
- MBTA contract administration and engineering.
- MBTA maintenance and operating expenses.
- Support or relocation of privately-owned utilities.
- Underpinning of structres adjacent to proposed subways.
- Clearance improvements in the Central Subway.
- Car-borne signal and communication equipment.
- Connection to supervisory control center.

All estimates are given with respect to 1969 construction prices except where 1970 estimated totals are indicated on summary sheets. Anticipated increases in cost may be estimated by using the Engineering News-Record Construction Cost Index shown in Figure 7-1.



Source: Engineering News-Record
March 19, 1971

Figure 7-1
CONSTRUCTION COST INDEX

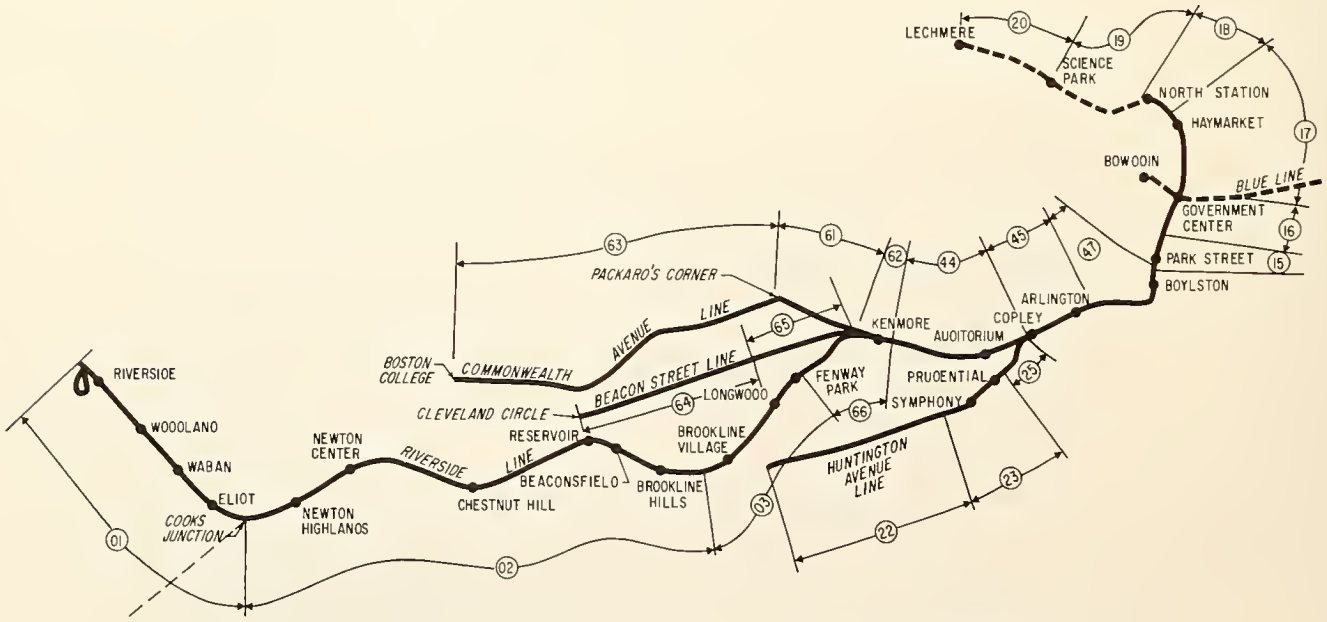
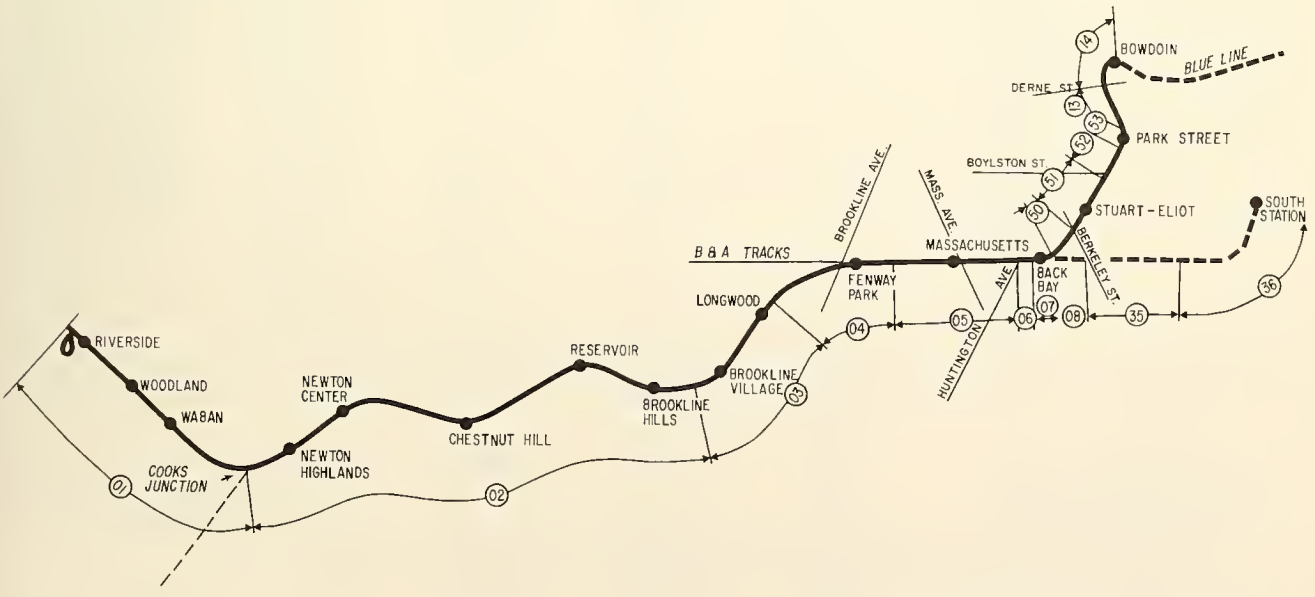


Figure 7-2
SEGMENTS OF STAGE I
SYSTEMS I, II & III

CASS - SYSTEM I - SUMMARY OF 1970 ESTIMATED COSTS

($1,000's)

Item	Stage 1	Stage 2	Stage 3	Stage 4	Totals
General Construction	175	13,488	23,794	54,941	92,398
Track & Roadbed	4,424	4,946	1,947	853	12,170
Traction Power	4,367	874	4,593	1,893	11,727
Signals	9,601	1,776	1,801	1,221	14,399
Communications	2,651	723	2,531	404	6,309
Totals	21,218	21,807	34,666	59,312	137,003



NOTE SEE FIGURE 7-2 FOR SEGMENTS OF OTHER GREEN LINES

Figure 7-3

SEGMENTS OF SYSTEM I

SYSTEM I - GENERAL CONSTRUCTION - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	20	--	4,614	--	4,634
02	25,525	85	--	3,816	--	3,901
03	7,100	10	--	1,409	--	1,419
04	2,750	--	895	200	--	1,095
05	4,600	--	1,032	200	--	1,232
06	800	--	808	--	--	808
07	750	--	2,534	300	--	2,834
50	750	--	--	--	3,903	3,903
51	1,750	--	--	--	7,622	7,622
52	1,440	--	--	--	7,524	7,524
53	440	--	--	--	8,901	8,901
13	1,070	--	--	--	5,262	5,262
14	825	--	--	--	2,913	2,913
62	1,000	--	--	--	--	--
65	1,500	--	--	--	--	--
66	3,600	--	--	--	--	--
44	4,200	--	--	--	--	--
45	3,000	--	--	--	--	--
47	1,700	--	--	--	--	--
15	1,100	--	--	500	--	500
16	1,000	--	--	--	--	--
17	1,570	--	--	--	--	--
18	1,180	--	--	3,555	--	3,555
19	2,500	--	--	250	--	250
20	3,000	--	--	300	--	300
23	2,530	--	--	--	--	--
25	1,100	--	--	--	--	--
08	200	--	800	--	--	800
35	3,000	--	1,800	200	--	2,000
36	3,000	--	1,000	300	--	1,300
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
22	5,980	--	--	--	--	--
Subtotals		115	8,869	15,644	36,125	60,753
15% Contingencies		17	1,330	2,347	5,419	9,113
15% Engineering and Supervision		20	1,530	2,699	6,231	10,480
Totals (1969)		152	11,729	20,690	47,775	80,346
Totals (1970)		175	13,488	23,794	54,941	92,398

SYSTEM I - TRACK & ROADBED - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	982	823	1,030	--	2,835
02	25,525	1,004	1,566	--	--	2,570
03	7,100	256	370	--	--	626
04	2,750	--	253	--	--	253
05	4,600	--	60	--	--	60
06	800	--	--	--	--	--
07	750	--	60	--	--	60
50	750	--	--	--	53	53
51	1,750	--	--	--	183	183
52	1,440	--	--	--	101	101
53	440	--	--	--	31	31
13	1,070	--	--	--	135	135
14	825	--	--	--	58	58
62	1,000	--	--	--	--	--
65	1,500	--	--	--	--	--
66	3,600	105	--	--	--	105
44	4,200	122	--	--	--	122
45	3,000	88	--	--	--	88
47	1,700	50	--	--	--	50
15	1,100	32	--	50	--	82
16	1,000	29	--	--	--	29
17	1,570	46	--	--	--	46
18	1,180	34	--	200	--	234
19	2,500	73	--	--	--	73
20	3,000	88	--	--	--	88
23	2,530	--	--	--	--	--
25	1,100	--	--	--	--	--
08	200	--	--	--	--	--
35	3,000	--	60	--	--	60
36	3,000	--	60	--	--	60
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
22	5,980	--	--	--	--	--
Subtotals		2,909	3,252	1,280	561	8,002
15% Contingencies		436	488	192	84	1,200
15% Engineering and Supervision		502	561	221	97	1,381
Totals (1969)		3,847	4,301	1,693	742	10,583
Totals (1970)		4,424	4,946	1,947	853	12,170

SYSTEM I - TRACTION POWER - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	924	--	826	--	1,750
02	25,525	1,570	--	81	--	1,651
03	7,100	117	8	673	--	798
04	2,750	--	103	620	--	723
05	4,600	--	172	--	--	172
06	800	--	39	--	--	39
07	750	--	27	335	24	386
50	750	--	--	--	24	24
51	1,750	--	--	--	56	56
52	1,440	--	--	--	334	334
53	440	--	--	--	386	386
13	1,070	--	--	--	250	250
14	825	--	--	--	170	170
62	1,000	--	--	16	--	16
65	1,500	--	--	24	--	24
66	3,600	46	--	--	--	46
44	4,200	67	--	--	--	67
45	3,000	48	--	--	--	48
47	1,700	27	--	--	--	27
15	1,100	18	--	--	--	18
16	1,000	16	--	--	--	16
17	1,570	25	--	--	--	25
18	1,180	2	--	18	--	20
19	2,500	5	--	5	--	10
20	3,000	6	--	6	--	12
23	2,530	--	--	41	--	41
25	1,100	--	--	24	--	24
08	200	--	7	--	--	7
35	3,000	--	112	--	--	112
36	3,000	--	107	25	--	132
61	6,400	--	--	37	--	37
63	14,600	--	--	138	--	138
64	13,500	--	--	117	--	117
22	5,980	--	--	34	--	34
Subtotals		2,871	575	3,020	1,244	7,710
15% Contingencies		431	86	453	187	1,157
15% Engineering and Supervision		495	99	521	215	1,330
Totals (1969)		3,797	760	3,994	1,646	10,197
Totals (1970)		4,367	874	4,593	1,893	11,727

SYSTEM I - SIGNALS - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	934	--	676	--	1,610
02	25,525	1,925	--	--	--	1,925
03	7,100	216	--	--	--	216
04	2,750	--	193	--	--	193
05	4,600	--	316	--	--	316
06	800	--	56	--	--	56
07	750	--	45	--	--	45
50	750	--	--	--	47	47
51	1,750	--	--	--	33	33
52	1,440	--	--	--	94	94
53	440	--	--	--	256	256
13	1,070	--	--	--	71	71
14	825	--	--	--	302	302
62	1,000	118	--	--	--	118
65	1,500	333	--	--	--	333
66	3,600	264	--	--	--	264
44	4,200	319	--	--	--	319
45	3,000	326	--	--	--	326
47	1,700	203	--	--	--	203
15	1,100	212	--	--	--	212
16	1,000	188	--	--	--	188
17	1,570	254	--	--	--	254
18	1,180	97	--	508	--	605
19	2,500	295	--	--	--	295
20	3,000	365	--	--	--	365
23	2,530	254	--	--	--	254
25	1,100	--	--	--	--	--
08	200	--	41	--	--	41
35	3,000	--	101	--	--	101
36	3,000	--	416	--	--	416
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
22	5,980	--	--	--	--	--
Subtotals		6,313	1,168	1,184	803	9,468
15% Contingencies		947	175	178	120	1,420
15% Engineering and Supervision		1,089	201	204	139	1,633
Totals (1969)		8,349	1,544	1,566	1,062	
Totals (1970)		9,601	1,776	1,801	1,221	14,399

SYSTEM I - COMMUNICATIONS - 1969 ESTIMATED COSTS

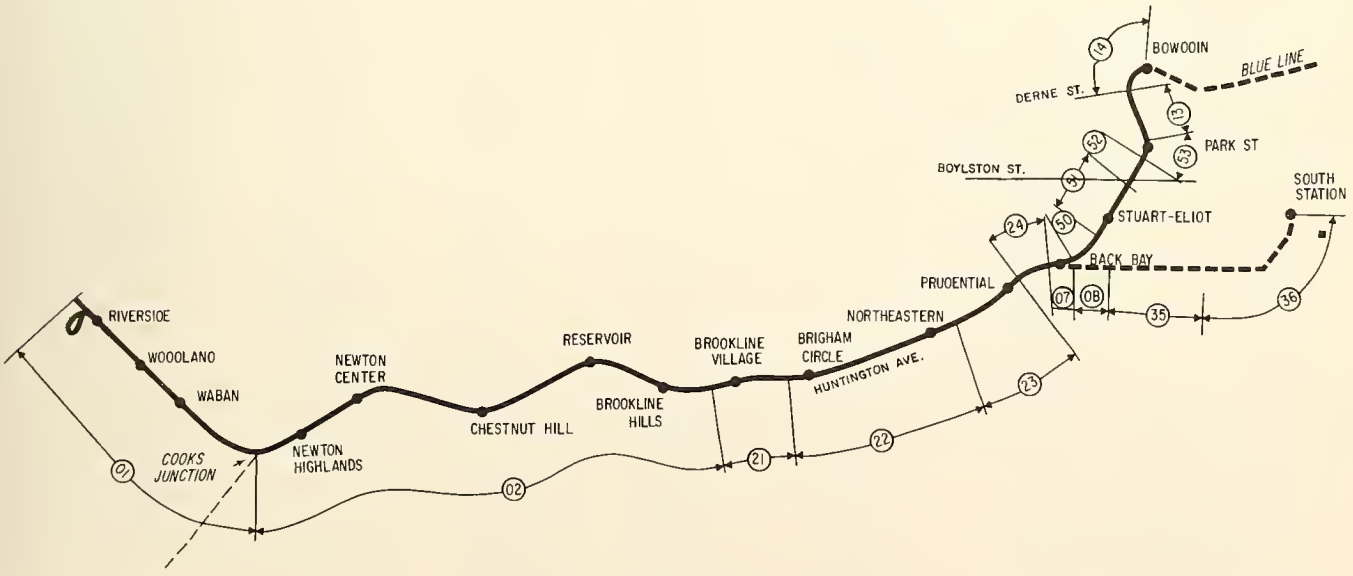
($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	--	--	602	--	602
02	25,525	508	--	647	--	1,155
03	7,100	129	--	16	--	145
04	2,750	--	79	24	--	103
05	4,600	--	132	--	--	132
06	800	--	23	--	--	23
07	750	--	41	--	--	41
50	750	--	--	--	24	24
51	1,750	--	--	--	30	30
52	1,440	--	--	--	64	64
53	440	--	--	--	42	42
13	1,070	--	--	--	44	44
14	825	--	--	--	61	61
62	1,000	54	--	24	--	78
65	1,500	115	--	47	--	162
66	3,600	89	--	--	--	89
44	4,200	150	--	79	--	229
45	3,000	122	--	39	--	161
47	1,700	63	--	24	--	87
15	1,100	61	--	12	--	73
16	1,000	42	--	6	--	48
17	1,570	45	--	24	--	69
18	1,180	59	--	63	--	122
19	2,500	70	--	--	--	70
20	3,000	98	--	--	--	98
23	2,530	138	--	57	--	195
25	1,100	--	--	--	--	--
08	200	--	35	--	--	35
35	3,000	--	71	--	--	71
36	3,000	--	95	--	--	95
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
22	5,980					
Subtotals		1,743	476	1,664	265	4,148
15% Contingencies		261	71	250	40	622
15% Engineering and Supervision		301	82	287	46	716
Totals (1969)		2,305	629	2,201	351	5,486
Totals (1970)		2,651	723	2,531	404	6,309

CASS - SYSTEM II - SUMMARY OF 1970 ESTIMATED COSTS

($1,000's)

Item	Stage 1	Stage 2	Stage 3	Stage 4	Totals
General Construction	175	18,418	76,493	55,034	150,120
Track & Roadbed	4,424	4,816	3,447	1,005	13,692
Traction Power	4,367	449	5,230	1,857	11,903
Signals	9,601	1,561	3,159	1,225	15,546
Communications	2,651	656	3,031	391	6,729
Totals	21,218	25,900	91,360	59,512	197,990



NOTE : SEE FIGURE 7-2 FOR SEGMENTS OF OTHER GREEN LINES

Figure 7-4
SEGMENTS OF SYSTEM II

SYSTEM II - GENERAL CONSTRUCTION - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	20	--	4,614	--	4,634
02	25,525	85	--	3,816	--	3,901
21	4,200	--	--	13,228	--	13,228
22	5,980	--	--	22,934	--	22,934
23	2,530	--	--	249	--	249
24	1,550	--	4,700	50	--	4,750
07	640	--	3,810	300	--	4,110
50	770	--	--	--	3,995	3,995
51	1,737	--	--	--	7,590	7,590
52	1,440	--	--	--	7,524	7,524
53	440	--	--	--	8,901	8,901
13	1,070	--	--	--	5,262	5,262
14	825	--	--	--	2,913	2,913
03	7,100	10	--	--	--	10
66	3,600	--	--	--	--	--
62	1,000	--	--	--	--	--
65	1,500	--	--	--	--	--
44	4,200	--	--	--	--	--
45	3,000	--	--	--	--	--
47	1,700	--	--	--	--	--
15	1,100	--	--	500	--	500
16	1,000	--	--	--	--	--
17	1,570	--	--	--	--	--
18	1,180	--	--	3,555	--	3,555
19	2,500	--	--	250	--	250
20	3,000	--	--	300	--	300
25	1,100	--	--	--	--	--
35	3,000	--	1,800	200	--	2,000
36	3,000	--	1,000	300	--	1,300
08	200	--	800	--	--	800
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
Subtotals		115	12,110	50,296	36,185	98,706
15% Contingencies		17	1,817	7,544	5,428	14,806
15% Engineering and Supervision		20	2,089	8,676	6,242	17,027
Totals (1969)		152	16,016	66,516	47,855	130,539
Totals (1970)		175	18,418	76,493	55,034	150,120

SYSTEM II - TRACK AND ROADBED - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	982	823	1,030	--	2,835
02	25,525	1,004	1,566	--	--	2,570
21	4,200	--	--	354	--	354
22	5,980	--	--	512	--	512
23	2,530	--	--	120	--	120
24	1,550	--	169	--	--	169
07	640	--	45	--	--	45
50	770	--	--	--	154	154
51	1,737	--	--	--	182	182
52	1,440	--	--	--	101	101
53	440	--	--	--	31	31
13	1,070	--	--	--	135	135
14	825	--	--	--	58	58
03	7,100	256	370	--	--	626
66	3,600	105	--	--	--	105
62	1,000	--	--	--	--	--
65	1,500	--	--	--	--	--
44	4,200	122	--	--	--	122
45	3,000	88	--	--	--	88
47	1,700	50	--	--	--	50
15	1,100	32	--	50	--	82
16	1,000	29	--	--	--	29
17	1,570	46	--	--	--	46
18	1,180	34	--	200	--	234
19	2,500	73	--	--	--	73
20	3,000	88	--	--	--	88
25	1,100	--	--	--	--	--
35	3,000	--	60	--	--	60
36	3,000	--	60	--	--	60
08	200	--	74	--	--	74
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
Subtotals		2,909	3,167	2,266	661	9,003
15% Contingencies		436	475	340	99	1,350
15% Engineering and Supervision		502	546	391	114	1,553
Totals (1969)		3,847	4,188	2,997	874	11,906
Totals (1970)		4,424	4,816	3,447	1,005	13,692

SYSTEM II - TRACTION POWER - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	924	--	826	--	1,750
02	25,525	1,570	--	120	--	1,690
21	4,200	--	--	777	--	777
22	5,980	--	--	836	--	836
23	2,530	--	--	89	--	89
24	1,550	--	42	56	--	98
07	640	--	19	349	--	368
50	770	--	--	--	25	25
51	1,737	--	--	--	56	56
52	1,440	--	--	--	334	334
53	440	--	--	--	386	386
13	1,070	--	--	--	250	250
14	825	--	--	--	170	170
03	7,100	117	--	--	--	117
66	3,600	46	--	--	--	46
62	1,000	--	--	16	--	16
65	1,500	--	--	24	--	24
44	4,200	67	--	--	--	67
45	3,000	48	--	--	--	48
47	1,700	27	--	--	--	27
15	1,100	18	--	--	--	18
16	1,000	16	--	--	--	16
17	1,570	25	--	--	--	25
18	1,180	2	--	18	--	20
19	2,500	5	--	5	--	10
20	3,000	6	--	6	--	12
25	1,100	--	--	--	--	--
35	3,000	--	111	--	--	111
36	3,000	--	113	--	--	113
08	200	--	10	25	--	35
61	6,400	--	--	37	--	37
63	14,600	--	--	138	--	138
64	13,500	--	--	117	--	117
Subtotals		2,871	295	3,439	1,221	7,826
15% Contingencies		431	44	516	183	1,174
15% Engineering and Supervision		495	51	593	211	1,350
Totals (1969)		3,797	390	4,548	1,615	10,350
Totals (1970)		4,367	449	5,230	1,857	11,903

SYSTEM II - SIGNALS - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	934	--	676	--	1,610
02	25,525	1,925	--	--	--	1,925
21	4,200	--	--	98	--	98
22	5,980	--	--	567	--	567
23	2,530	254	196	--	--	450
24	1,550	--	47	--	--	47
07	640	--	45	--	--	45
50	770	--	--	--	47	47
51	1,737	--	--	--	35	35
52	1,440	--	--	--	94	94
53	440	--	--	--	256	256
13	1,070	--	--	--	71	71
14	825	--	--	--	302	302
03	7,100	216	--	208	--	424
66	3,600	264	--	--	--	264
62	1,000	118	--	--	--	118
65	1,500	333	--	--	--	333
44	4,200	319	--	--	--	319
45	3,000	326	--	--	--	326
47	1,700	203	--	--	--	203
15	1,100	222	--	--	--	222
16	1,000	188	--	--	--	188
17	1,570	254	--	--	--	254
18	1,180	97	--	528	--	625
19	2,500	295	--	--	--	295
20	3,000	365	--	--	--	365
25	1,100	--	179	--	--	179
35	3,000	--	102	--	--	102
36	3,000	--	416	--	--	416
08	200	--	41	--	--	41
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
Subtotals		6,313	1,026	2,077	805	10,221
15% Contingencies		947	154	312	121	1,534
15% Engineering and Supervision		1,089	177	358	139	1,763
Totals (1969)		8,349	1,357	2,747	1,065	13,518
Totals (1970)		9,601	1,561	3,159	1,225	15,546

SYSTEM II - COMMUNICATIONS - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	--	--	602	--	602
02	25,525	508	--	647	--	1,155
21	4,200	--	--	67	--	67
22	5,980	--	--	262	--	262
23	2,530	138	152	57	--	347
24	1,550	--	41	--	--	41
07	640	--	41	--	--	41
50	770	--	--	--	24	24
51	1,737	--	--	--	30	30
52	1,440	--	--	--	64	64
53	440	--	--	--	53	53
13	1,070	--	--	--	44	44
14	825	--	--	--	42	42
03	7,100	129	--	16	--	145
66	3,600	89	--	24	--	113
62	1,000	54	--	24	--	78
65	1,500	115	--	47	--	162
44	4,200	150	--	79	--	229
45	3,000	122	--	39	--	161
47	1,700	63	--	24	--	87
15	1,100	61	--	12	--	73
16	1,000	42	--	6	--	48
17	1,570	45	--	24	--	69
18	1,180	59	--	63	--	122
19	2,500	70	--	--	--	70
20	3,000	98	--	--	--	98
25	1,100	--	--	--	--	--
35	3,000	--	71	--	--	71
36	3,000	--	91	--	--	91
08	200	--	35	--	--	35
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
Subtotals		1,743	431	1,993	257	4,424
15% Contingencies		261	65	299	39	664
15% Engineering and Supervision		301	74	344	44	763
Totals (1969)		2,305	570	2,636	340	5,851
Totals (1970)		2,651	656	3,031	391	6,729

CASS - SYSTEM III - SUMMARY OF 1970 ESTIMATED COSTS

($1,000's)

Item	Stage 1	Stage 2	Stage 3	Stage 4	Totals
General Construction	175	21,738	75,931	31,482	129,326
Track & Roadbed	4,424	5,063	4,022	913	14,422
Traction Power	4,367	536	7,699	241	12,843
Signals	9,601	2,160	3,434	1,508	16,703
Communications	2,651	870	2,844	504	6,869
Totals	21,218	30,367	93,930	34,648	180,163

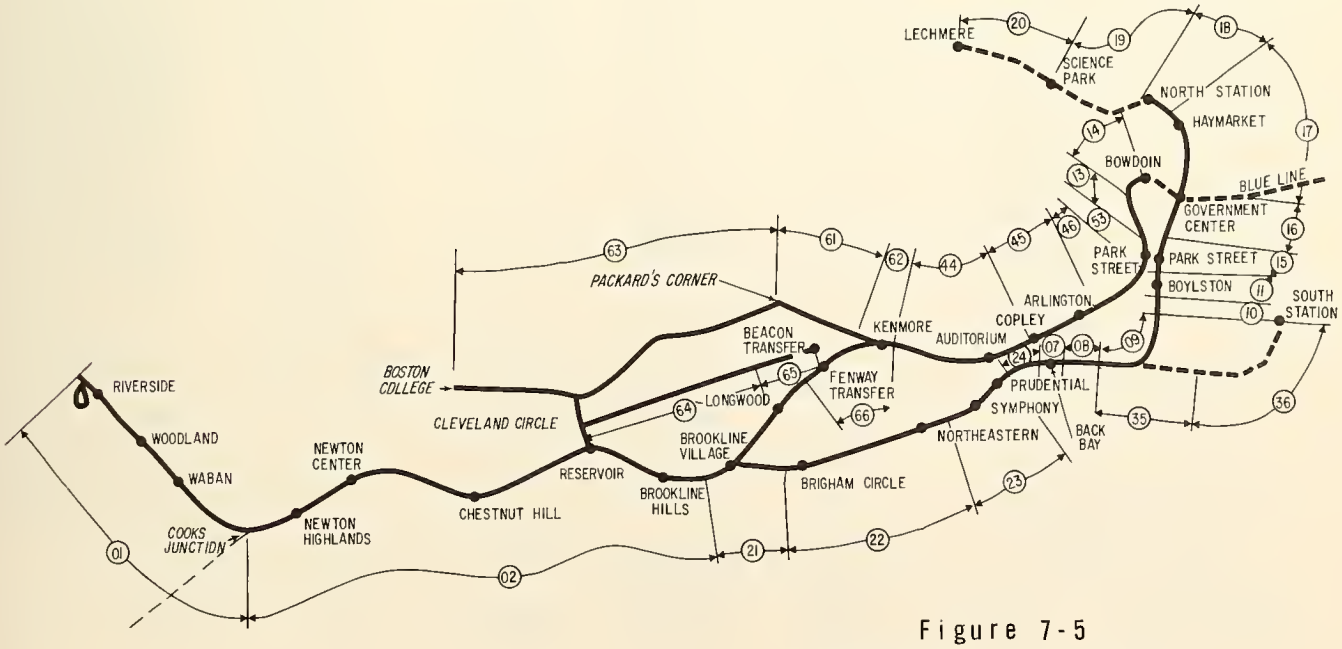


Figure 7-5

SEGMENTS OF SYSTEM III

SYSTEM III - GENERAL CONSTRUCTION - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	20	--	4,614	--	4,634
02	25,525	85	--	3,816	--	3,901
03	7,100	10	--	1,409	--	1,419
62	1,000	--	--	--	--	--
65	1,500	--	3,705	--	--	3,705
66	3,600	--	3,555	370	--	3,925
44	4,200	--	--	212	--	212
45	3,000	--	--	461	--	461
46	1,730	--	--	7,238	--	7,238
53	440	--	--	8,901	--	8,901
13	1,070	--	--	5,262	--	5,262
14	825	--	--	2,913	--	2,913
21	3,250	--	--	--	12,500	12,500
22	5,980	--	--	--	8,200	8,200
23	2,530	--	--	--	--	--
24	1,470	--	3,601	--	--	3,601
07	760	--	632	--	--	632
08	200	--	--	--	--	--
09	2,700	--	--	10,494	--	10,494
10	500	--	--	50	--	50
11	800	--	--	80	--	80
15	1,100	--	--	--	--	--
16	1,000	--	--	--	--	--
17	1,570	--	--	--	--	--
18	1,180	--	--	3,555	--	3,555
19	2,500	--	--	250	--	250
20	3,000	--	--	300	--	300
47	1,700	--	--	--	--	--
25	1,100	--	--	--	--	--
35	3,000	--	1,800	--	--	1,800
36	3,000	--	1,000	--	--	1,000
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
Subtotals		115	14,293	49,925	20,700	85,033
15% Contingencies		17	2,144	7,489	3,105	12,755
15% Engineering and Supervision		20	2,466	8,612	3,571	14,669
Totals (1969)		152	18,903	66,026	27,376	112,457
Totals (1970)		175	21,738	75,931	31,482	129,326

SYSTEM III - TRACK & ROADBED - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	982	823	1,030	--	2,835
02	25,525	1,004	1,566	--	--	2,570
03	7,100	256	370	--	--	626
62	1,000	--	--	--	--	--
65	1,500	--	--	--	--	--
66	3,600	105	300	--	--	405
44	4,200	122	--	--	--	122
45	3,000	88	--	--	--	88
46	1,730	--	--	170	--	170
53	440	--	--	31	--	31
13	1,070	--	--	135	--	135
14	825	--	--	58	--	58
21	3,250	--	--	--	400	400
22	5,980	--	--	--	200	200
23	2,530	--	--	--	--	--
24	1,470	--	150	--	--	150
07	760	--	--	--	--	--
08	200	--	--	--	--	--
09	2,700	--	--	220	--	220
10	500	--	--	300	--	300
11	800	--	--	500	--	500
15	1,100	32	--	--	--	32
16	1,000	29	--	--	--	29
17	1,570	46	--	--	--	46
18	1,180	34	--	200	--	234
19	2,500	73	--	--	--	73
20	3,000	88	--	--	--	88
47	1,700	50	--	--	--	50
25	1,100	--	--	--	--	--
35	3,000	--	60	--	--	60
36	3,000	--	60	--	--	60
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
Subtotals		2,909	3,329	2,644	600	9,482
15% Contingencies		436	500	397	90	1,422
15% Engineering and Supervision		502	574	456	104	1,637
Totals (1969)		3,847	4,403	3,497	794	12,541
Totals (1970)		4,424	5,063	4,022	913	14,422

SYSTEM III - TRACTION POWER - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	924	--	826	--	1,750
02	25,525	1,570	10	81	--	1,661
03	7,100	117	--	673	--	790
62	1,000	--	--	16	--	16
65	1,500	--	10	14	--	24
66	3,600	46	24	718	--	788
44	4,200	67	--	345	--	412
45	3,000	48	--	600	--	648
46	1,730	--	--	350	--	350
53	440	--	--	388	--	388
13	1,070	--	--	254	--	254
14	825	--	--	174	--	174
21	3,250	--	--	--	96	96
22	5,980	--	--	34	63	97
23	2,530	--	--	41	--	41
24	1,470	--	44	22	--	66
07	760	--	30	11	--	41
08	200	--	10	23	--	33
09	2,700	--	--	126	--	126
10	500	--	--	8	--	8
11	800	--	--	13	--	13
15	1,100	18	--	25	--	43
16	1,000	16	--	--	--	16
17	1,570	25	--	--	--	25
18	1,180	2	--	18	--	20
19	2,500	5	--	5	--	10
20	3,000	6	--	6	--	12
47	1,700	27	--	--	--	27
25	1,100	--	--	--	--	--
35	3,000	--	111	--	--	111
36	3,000	--	113	--	--	113
61	6,400	--	--	37	--	37
63	14,600	--	--	138	--	138
64	13,500	--	--	117	--	117
Subtotals		2,871	352	5,063	159	8,445
15% Contingencies		431	53	759	24	1,267
15% Engineering and Supervision		495	61	873	27	1,456
Totals (1969)		3,797	466	6,695	210	11,168
Totals (1970)		4,367	536	7,699	241	12,843

SYSTEM III - SIGNALS - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	934	--	676	--	1,610
02	25,525	1,925	--	--	--	1,925
03	7,100	216	--	--	--	216
62	1,000	118	220	--	--	338
65	1,500	333	220	--	--	553
66	3,600	264	134	--	--	398
44	4,200	319	--	--	--	319
45	3,000	326	--	--	--	326
46	1,730	--	--	253	--	253
53	440	--	--	256	--	256
13	1,070	--	--	71	--	71
14	825	--	--	302	--	302
21	3,250	--	--	--	424	424
22	5,980	--	--	--	567	567
23	2,530	254	--	--	--	254
24	1,470	--	47	--	--	47
07	760	--	45	--	--	45
08	200	--	41	--	--	41
09	2,700	--	--	92	--	92
10	500	--	--	29	--	29
11	800	--	--	50	--	50
15	1,100	222	--	--	--	222
16	1,000	188	--	--	--	188
17	1,570	254	--	--	--	254
18	1,180	97	--	529	--	626
19	2,500	295	--	--	--	295
20	3,000	365	--	--	--	365
47	1,700	203	--	--	--	203
25	1,100	--	196	--	--	196
35	3,000	--	101	--	--	101
36	3,000	--	416	--	--	416
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
Subtotals		6,313	1,420	2,258	991	10,982
15% Contingencies		947	213	339	149	1,648
15% Engineering and Supervision		1,089	245	389	171	1,894
Totals (1969)		8,349	1,878	2,986	1,311	14,524
Totals (1970)		9,601	2,160	3,434	1,508	16,703

SYSTEM III - COMMUNICATIONS - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Stage 1	Stage 2	Stage 3	Stage 4	Segment Totals
01	16,100	--	--	602	--	602
02	25,525	508	--	647	--	1,155
03	7,100	129	--	16	--	145
62	1,000	54	42	--	--	96
65	1,500	115	47	--	--	162
66	3,600	89	47	--	--	136
44	4,200	150	--	79	--	229
45	3,000	122	--	39	--	161
46	1,730	--	--	107	--	107
53	440	--	--	53	--	53
13	1,070	--	--	44	--	44
14	825	--	--	42	--	42
21	3,250	--	--	--	69	69
22	5,980	--	--	--	262	262
23	2,530	138	153	--	--	291
24	1,470	--	41	--	--	41
07	760	--	41	--	--	41
08	200	--	35	--	--	35
09	2,700	--	--	62	--	62
10	500	--	--	25	--	25
11	800	--	--	25	--	25
15	1,100	61	--	12	--	73
16	1,000	42	--	6	--	48
17	1,570	45	--	24	--	69
18	1,180	59	--	63	--	122
19	2,500	70	--	--	--	70
20	3,000	98	--	--	--	98
47	1,700	63	--	24	--	87
25	1,100	--	--	--	--	--
35	3,000	--	71	--	--	71
36	3,000	--	95	--	--	95
61	6,400	--	--	--	--	--
63	14,600	--	--	--	--	--
64	13,500	--	--	--	--	--
Subtotals		1,743	572	1,870	331	4,516
15% Contingencies		261	86	281	50	678
15% Engineering and Supervision		301	99	322	57	779
Totals (1969)		2,305	757	2,473	438	5,973
Totals (1970)		2,651	870	2,844	504	6,869

CASS - WESTERN CORRIDOR - SUMMARY OF 1970 ESTIMATED COSTS

($1,000's)

Item	NEEDHAM EXTENSION		EXTENSION ALONG PENN-CENTRAL RAILROAD	
	Needham Junction to Needham Heights	Needham Heights to Cooks Junction	Framingham to Riverside	Riverside to Fenway
General Construction	34,179	7,890	15,827	9,049
Track & Roadbed	1,454	2,084	6,301	3,381
Traction Power	1,310	1,525	6,997	5,229
Signals	741	2,207	5,357	4,996
Communications	438	645	2,492	1,919
Totals	38,122	14,352	36,974	24,574

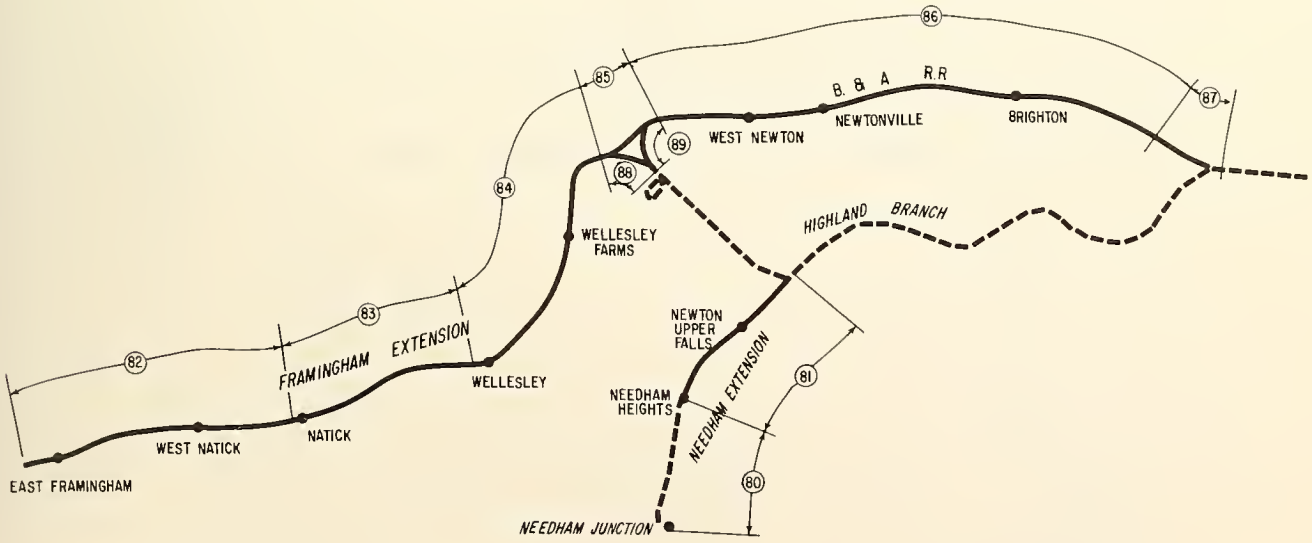


Figure 7-6

SEGMENTS OF PROPOSED ROUTES IN THE WESTERN CORRIDOR

WESTERN CORRIDOR - GENERAL CONSTRUCTION - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Needham Extension: Needham Junction to Needham Heights	Needham Extension: Needham Heights to Cooks Junction	Extension along Penn - Central: Framingham to Riverside	Extension along Penn - Central: Riverside to Fenway Park
80	7,500	22,473	--	--	--
81	12,400	--	5,188	--	--
82	16,950	--	--	2,603	--
83	15,150	--	--	3,384	--
84	19,600	--	--	3,920	--
88	1,675	--	--	500	--
89	1,950	--	--	--	--
85	2,000	--	--	--	--
86	38,000	--	--	--	2,250
87	5,850	--	--	--	3,700
Subtotals		22,473	5,188	10,407	5,950
15% Contingencies		3,371	778	1,561	893
15% Engineering and Supervision		3,877	895	1,795	1,026
Totals (1969)		29,721	6,861	13,763	7,869
Totals (1970)		34,179	7,890	15,827	9,049

WESTERN CORRIDOR - TRACK AND ROADBED - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Needham Extension: Needham Junction to Needham Heights	Needham Extension: Needham Heights to Cooks Junction	Extension along Penn - Central: Framingham to Riverside	Extension along Penn - Central: Riverside to Fenway Park
80	7,500	956	--	--	--
81	12,400	--	1,370	--	--
82	16,950	--	--	1,422	--
83	15,150	--	--	1,140	--
84	19,600	--	--	1,458	--
88	1,675	--	--	123	--
89	1,950	--	--	--	185
85	2,000	--	--	--	68
86	38,000	--	--	--	1,652
87	5,850	--	--	--	318
Subtotals		956	1,370	4,143	2,223
15% Contingencies		143	206	621	333
15% Engineering and Supervision		165	236	715	384
Totals (1969)		1,264	1,812	5,479	2,940
Totals (1970)		1,454	2,084	6,301	3,381

WESTERN CORRIDOR - TRACTION POWER - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Needham Extension: Needham Junction to Needham Heights	Needham Extension: Needham Heights to Cooks Junction	Extension along Penn - Central: Framingham to Riverside	Extension along Penn - Central: Riverside to Fenway Park
80	7,500	861	--	--	--
81	12,400	--	1,003	--	--
82	16,950	--	--	1,638	--
83	15,150	--	--	1,089	--
84	19,600	--	--	1,793	--
88	1,675	--	--	80	--
89	1,950	--	--	--	71
85	2,000	--	--	--	71
86	38,000	--	--	--	3,068
87	5,850	--	--	--	228
Subtotals		861	1,003	4,600	3,438
15% Contingencies		129	150	690	516
15% Engineering and Supervision		149	173	794	593
Totals (1969)		1,139	1,326	6,084	4,547
Totals (1970)		1,310	1,525	6,997	5,229

WESTERN CORRIDOR - SIGNALS - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Needham Extension: Needham Junction to Needham Heights	Needham Extension: Needham Heights to Cooks Junction	Extension along Penn - Central: Framingham to Riverside	Extension along Penn - Central: Riverside to Fenway Park
80	7,500	487	--	--	--
81	12,400	--	1,451	--	--
82	16,950	--	--	1,357	--
83	15,150	--	--	575	--
84	19,600	--	--	972	--
88	1,675	--	--	618	--
89	1,950	--	--	--	177
85	2,000	--	--	--	400
86	38,000	--	--	--	2,075
87	5,850	--	--	--	632
Subtotals		487	1,451	3,522	3,284
15% Contingencies		73	218	528	493
15% Engineering and Supervision		84	250	608	567
Totals (1969)		644	1,919	4,658	4,344
Totals (1970)		741	2,207	5,357	4,996

WESTERN CORRIDOR - COMMUNICATIONS - 1969 ESTIMATED COSTS

($1,000's)

Segment No.	Length Ft.	Needham Extension: Needham Junction to Needham Heights	Needham Extension: Needham Heights to Cooks Junction	Extension along Penn - Central: Framingham to Riverside	Extension along Penn - Central: Riverside to Fenway Park
80	7,500	288	--	--	--
81	12,400	--	424	--	--
82	16,950	--	--	596	--
83	15,150	--	--	422	--
84	19,600	--	--	503	--
88	1,675	--	--	117	--
89	1,950	--	--	--	90
85	2,000	--	--	--	95
86	38,000	--	--	--	904
87	5,850	--	--	--	173
Subtotals		288	424	1,638	1,262
15% Contingencies		43	64	246	189
15% Engineering and Supervision		50	73	283	218
Totals (1969)		381	561	2,167	1,669
Totals (1970)		438	645	2,492	1,919

BIBLIOGRAPHY

Clearance Test with New Clearance Car for Proposed No. 6 Surface Car. Massachusetts Bay Transportation Authority, June 16, 1970.

Type No. 6 Surface Rail Cars. Massachusetts Bay Transportation Authority, April 22, 1970.

The Rapid Transit Plan for the Metropolitan Seattle Area. De Leuw, Cather & Company, et al., March 19, 1970.

Washington Metropolitan Area Transit Authority, Rapid Transit System. Manual of Design Criteria. De Leuw, Cather & Company, March 9,1970.

CASS, The Automated Corridor Model and its Application to Western and North Shore Corridors. Peat, Marwick, Mitchell & Company, Boston, Massachusetts, February 1970.

Request for Increased Bonding Authorization for the Continuation of the Program for Massachusetts Transportation. Massachusetts Bay Transportation Authority, January 1970.

CASS Downtown Rapid Transit Distribution System Study. Peat, Marwick, Mitchell & Company, December 1969.

Project Biped, Bi-Powered Equipment Development. Massachusetts Bay Transportation Authority, October 31, 1969.

Traffic - COP, Proposals to Expedite the Flow of Train Traffic Through Copley Junction. Massachusetts Bay Transportation Authority, September 2, 1969.

New Green Line Car - Door Configuration. Massachusetts Bay Transportation Authority, June 23, 1969.

Surface Car Line Operations Study, Beacon Street-Green Line, Brookline and Boston. Bruce Campbell & Associates, May 1969.

Southwest Transit Corridor - Area 2, South Cove to New Heath Street, Supplemental Report No. 1. Clarkeson & Clough Associates, February 13, 1969.

Transportation Systems in the Future Development of Metropolitan Areas. Jack E. Leisch, De Leuw, Cather & Company of Canada Limited, January 1969.

Application of the Massachusetts Bay Transportation Authority for a Supplemental Technical Studies Grant for the Central Area Systems Study under the Urban Mass Transportation Act of 1964 as Amended. Massachusetts Bay Transportation Authority, December 23, 1968.

Kenmore Square By-Pass Study, B. U. Bridge to Massachusetts Avenue. Planning, Engineering and Development Consulting Engineers, November 1968.

New England Regional Commission, Regional Transportation Needs. Systems Analysis and Research Corporation, November 1968.

Washington Metropolitan Area Transit Authority, Rapid Transit Development Program. Trackwork Study, Volume II. De Leuw, Cather & Company, August 1968.

Central Area Systems Study, Tremont Street Subway Extension, Engineering Design Study. Parsons, Brinckerhoff, Quade & Douglas, Inc., June 18, 1968.

Application of the Massachusetts Bay Transportation Authority for a Technical Studies Grant for the Central Area Systems Study under the Urban Mass Transportation Act of 1964 as Amended. Massachusetts Bay Transportation Authority, May 27, 1968.

The Lab is the City. Boston Redevelopment Authority, May 1968.

Transit Planning Study Chicago Central Area. De Leuw, Cather & Company, et al., April 1968.

Preliminary Engineering Report for Rapid Transit Extension, Harvard Square-Alewife Brook. Sverdrup & Parcel and Associates, Inc., February 1968.

Transit Fact Book. American Transit Association, 1968.

Recommended Highway and Transit Plan. Massachusetts Department of Public Works, 1968.

Trackwork Study, Volume I, Trackwork Practices of North American Rapid Transit Systems. De Leuw, Cather & Company, November 1967.

Report on a Comprehensive Public Transportation Plan for the Seattle Metropolitan Area. De Leuw, Cather & Company, et al., October 1967.

Transportation Facts for the Boston Region, Boston Redevelopment Authority, 1967.

Safety and Traffic Operations Study, Huntington Avenue, Boston, Massachusetts. Planning, Engineering & Development, Consulting Engineers, October 1967.

Manchester Rapid Transit Study. De Leuw, Cather & Partners and Hennessey, Chadwick, O'Heocha & Partners, August 1967.

Boston Urban Transit Master Scheme 2000 AD. Lockwood Greene Engineers, Inc., August 1967.

Massachusetts Bay Transportation Authority, Central Area Systems Study, Phase I Report. Gibbs & Hill, Inc., July 1967.

New Green Line Car Outline of Characteristics. Massachusetts Bay Transportation Authority, May 19, 1967.

Station Modernization Program. Massachusetts Bay Transportation Authority, March 31, 1967.

Report on Improving the Boston-Brookline Streets & Highways in the Vicinity of Jamaicaway-Riverway. Fay, Spofford & Thorndike, Inc., 1967.

Planning District Analysis. City of Newton, Massachusetts, 1967.

Basic Design Report Inner Belt and Southwest Expressways I-95 and I-695 in the City of Boston. Clarkeson Engineering Co., Inc., May 1966.

European Tram Train and European Tram Train Subway-Surface System Report. Massachusetts Bay Transportation Authority. Fred G. Gale and William O. Adams, January 4, 1966.

Master Plan for the Town of Needham, Massachusetts. Shurcliff and Merrill, January 1966.

Proposed MBTA System Improvements. Boston Redevelopment Authority, 1966.

Report to the Advisory Board of the Massachusetts Bay Transportation Authority on the Proposed South Shore Express Transit Project. Massachusetts Bay Transportation Authority, November 29, 1965.

Geometric Standards and Bridge Design Specifications. Massachusetts Bay Transportation Authority, November 1965.

Comprehensive Traffic and Transportation Inventory. Wilbur Smith and Associates, September 1965.

Utilization of Existing Rail Facilities for Mass Transit Service in Louisville and Jefferson County, September 1965.

Comprehensive Plan. Wellesley Planning Board, August 1965.

The Central Subway System of the Massachusetts Bay Transportation Authority. William O. Adams, July 1965.

Summary 1965/1975 General Plan for the City of Boston and the Regional Core. Boston Redevelopment Authority, March 1965.

Supplementary Rapid Transit Studies Covering Extensions to West Roxbury, Needham, Dedham, Westwood and Norwood. De Leuw, Cather & Company, April 1965.

Master Plan. Weston, Massachusetts, 1965.

General Plan. Newton, Massachusetts, 1965.

Proposed Extension of Main Line Rapid Transit Facilities over the New York, New Haven and Hartford Railroad from Washington Street Tunnel to Route 128 in Dedham. De Leuw, Cather & Company, July 1964.

Proposed Extension of Cambridge Subway Rapid Transit Facilities to Concord Turnpike. De Leuw, Cather & Company, June 1964.

The Transportation Problem of Boston, Massachusetts. Metropolitan Transit Authority, February 26, 1964.

1964 Cordon Count Downtown Boston. Boston Traffic and Parking Commission, 1964.

North Terminal Area Study. Barton-Aschman Associates, Inc.; Alfred Benesch and Company; Col. S. H. Bingham (Ret.); August 1962.

The Metropolitan Transit Authority and Proposed Rapid Transit Extensions to Needham. James H. Powers, July 29, 1960.

Proposed Subway Facilities Required to Meet Additional Loads from the Prudential and Government Center Projects. Metropolitan Transit Authority Engineering Department, March 1959.

Report Regarding the Proposed Stuart Street Subway and Extension and Alterations to Existing Subways. De Leuw, Cather & Company, December 1958.

Report Regarding Transit Operations on the Newton Highlands Branch of the Boston and Albany Railroad. Metropolitan Transit Authority, February 1957.

Rapid Transit Lines In Boston. Massachusetts Bay Transportation Authority.

Report of the Legislative Commission on Rapid Transit. Commonwealth of Massachusetts, 1947.

Report on Improved Transit Facilities in the Boston Metropolitan District. Commonwealth of Massachusetts, Division of Metropolitan Planning, December 1926.

Paul Revere Park

APPENDICES

MASSACHUSETTS
BAY
TRANSPORTATION
AUTHORITY

Appendix A

DESIGN CRITERIA

The principal criteria that govern the design of engineering and architectural features of CASS are listed below. These criteria are consonant with current policies of the Massachusetts Bay Transportation Authority. They have been applied with uniformity to all design situations.

Technological progress and changes in economic conditions have caused some departure from previously accepted practices. Wherever possible, full advantage has been taken of such advances. Useful innovations have been incorporated into these criteria to make them representative of progressive methods in current transportation engineering.

RAPID TRANSIT CAR DATA

Clearances, alignment, power and other design requirements are dependent upon the type of rolling stock being used. All studies in CASS, unless specifically noted otherwise, are based on the specifications of the No. 5 Red Line rapid transit car, which has the following dimensions:

Length between anti-climbers	69'-6"
Truck centers	51'-0"
Top of rail to top of car	12'-5 13/16"
Width over door signal lights	10'-5 1/4"
Width over side doors	10'-1 15/16"
Width over thresholds	9'-6"
Top of rail to car floor	4'-1"

ALIGNMENT AND PROFILE

Clearances

Top of rail to overhead obstruction in subway	14'-9"
Top of rail to top of platform	3'-11 1/2"
Centerline of track to edge of platform	5'-0"
Track gauge	4'-8 1/2"
Centerline of track to fixed obstruction	7'-1 1/4"

Centerline of track to obstruction on station platform	13'-0"
Centerline of track to obstruction on track bridge	6'-6"
Centerline of track to fixed obstruction (walkway side)	8'-6"

NOTE: The above clearances shall be adjusted for car overhang and superelevation on curved track.

Horizontal Alignment

At stations, minimum radius	4,000'
Between stations, desirable minimum radius	2,000'
Station approach, minimum radius	1,000'
Between stations, absolute minimum radius	500'
Yard, minimum radius	150'

Superelevation

Maximum actual, main line	6"
Maximum actual, yard and stations	1"
Maximum unbalance, where necessary	3"
Runoff, linear throughout length of spiral, maximum rate	.00167
Length of spiral	AREA
Minimum length of spiral	100'

Vertical Alignment

Grades:

Maximum allowed	4.5%
Maximum preferred	3.0%
Maximum at station platform	0.5%

Vertical Curves:

See "Geometric Standards", MBTA	
Minimum length, parabolic curve	100'

Elevation Datum:

100.00 feet below Boston City Base,
105.65 feet below USC & GS mean sea level datum of 1929

Design Speed

Design speed

Highland Branch	55 mph
Western Corridor	65 mph

Operating speed between stations (except where limited by alignment restrictions)	Same as design speeds
Maximum operating speed at station platforms	20 mph
Rate of acceleration	3.0 mph/sec
Rate of deceleration, normal	3.0 mph/sec
Rate of deceleration, emergency	3.5 mph/sec

TRACKWORK

Rail

Main line	AREA 115 lbs.
Yard	AREA 100 lbs.
Contact rail	150 lbs.
Restraining rail, on inside rail of all main line curves having radius less than 1,000'	
Guard rail, on bridges and high fills, 100' extensions	
Continuous shop-welded rail, maximum length	1,500'

Thermite full fushion field welds to be used.
Heat treatment:
Both rails if radius less than or equal to 1,500'
High rail if radius greater than 1,500'
Elastomeric tie pads to be used.

Special Trackwork

Turnouts:

Main line junction	AREA No. 20
Main line crossover	AREA No. 12
Main line emergency crossover	AREA No. 10
Yard, minimum	AREA No. 5

Locate on tangent track and uniform grades, if possible.
All switch points to be fully guarded.
Solid manganese frogs except in yards.
Electric switch heaters at all locations on surface.
Diamond crossovers will be used only where absolutely necessary.

Ties

Surface, on ballast:

Two-block concrete, spaced 30" o.c.
Creosote-treated timber at special trackwork.

Subway:

Direct fixation to concrete invert.
Creosote-treated timber at special trackwork, on ballast.
Contact rail support spaced 10'-0" o.c.

Ballast:

Crushed granite, 1 1/4", minimum depth 12" under tie.
Sub-ballast, 6" depth, to be used where required.

Structures

Specifications and Codes

The following standard specifications and codes govern designs except as modified by MBTA design standards or local building codes:

Structures supporting transit loads	AREA
Structures supporting highway loads	ASHO
Stations and Buildings	AISC and ACI

See Appendix C for a discussion of subway construction methods.

Stations

Station planning is governed by the MBTA Manual of Guidelines and Standards.

Station concepts reflect the importance that is ascribed to these objectives:

1. Inviting exterior appearance.
2. Spacious and bright interior.
3. Efficient passenger flow pattern.
4. Maximum surveillance potential.
5. Capital and maintenance economy.

Traction Power

See Appendix E.

Signals and Communications

See Chapter 3 for a description of proposed signal and communication installations.

Appendix B

ARCHITECTURAL DESIGN

DESIGN CRITERIA

The basis for preliminary station and terminal layouts was the Manual of Guidelines and Standards of the Massachusetts Bay Transportation Authority. Particular attention was given to the contents of Part X, Site Planning and New Stations.

ENVIRONMENTAL CONSIDERATIONS

Transit stations should be attractive to patrons as well as functional in operation. Although the primary goal of a rider is a fast trip to his destination, the experience should be a pleasant one for him--one that he will want to repeat and recommend to others.

The community through which the transit facility passes should benefit from the attractiveness of the stations as well as from the usefulness of its service. Stations should be easily identified by potential riders and visually inviting to them. Transfer from bus or auto to trains should be as efficient as possible, generating minimum interference with normal activities in the surrounding area.

STATION DESIGNS

Subway Stations

Subway stations have been planned wherever possible to provide centralized fare collection serving a center platform below. They have

been located as near the surface as possible to reduce cost and minimize the amount of vertical travel for patrons.

At-Grade Stations

Side platforms have been retained in most locations to avoid reconstruction of bridges, introduction of additional reverse curves into the alignment and property taking.

Access into station lobbies is very often directly from bridge or street level. The patron enters the lobby, passes concessions and turnstiles, decides which direction to take and uses stairway or reversible escalator down to platform level.

These stations are envisioned as rather spacious, with clear spans between side walls, allowing a view of the approaching trains from within the lobby and during descent to the platform. The patron should experience a sensation of well-being and of purposeful direction during the few moments he is within the station.

Platforms have translucent canopies that allow greater brightness during daylight hours and make the stations more attractive and easily located at evening. Arch-rib supports for the canopies also support the catenary overhead power source for transit car operations. Designs of canopy bays are modular to take advantage of economies that can result from mass production techniques.

Terminal Stations

Special conditions apply at each of the proposed terminal stations. However, the following design features are found in each one:

Center platform to handle large numbers of people in a single direction at one time;

Efficient bus-to-rail transfer facilities;

Adequate parking facilities;

Kiss 'n' ride provisions.

Since passenger loads at terminal stations are particularly heavy during peak hours, additional capacity such as extra agents and adequate numbers of turnstiles are essential features in these installations.

Appendix C

STRUCTURAL DESIGN

Underground construction in a heavily populated urban area usually causes some disruption of normal activities. Noisy heavy equipment, trucks carrying excavated soil and building materials, traffic detours and other temporary inconveniences are familiar to the city dweller, who tolerates such disturbances to gain long-term improvements.

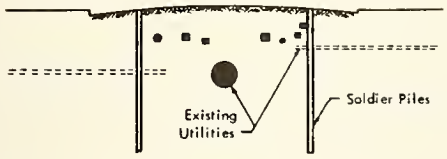
The construction methods proposed in this study were selected for economy as well as for their suitability to particular urban situations. These methods are described below to supplement information in Chapter 4.

CUT-AND-COVER CONSTRUCTION

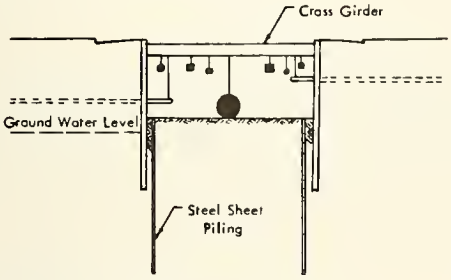
The term cut-and-cover construction is used to describe the excavation, or cutting, of a trench in which a subway box is built, and the subsequent backfilling, or covering, with compacted soil to restore the surface. When subways are built in this matter, related problems must be solved. Subway routes frequently follow major city streets, and street traffic must be temporarily re-routed to permit construction. In addition, utilities in the streets must be supported or relocated. Close coordination has to be achieved between the various utility companies and subway contractors. This problem may be alleviated somewhat by the cut-and-cover method which permits work to begin at any point, or at several points, along a subway route.

Stages in building a subway by the cut-and-cover method are illustrated in Figure C-1.

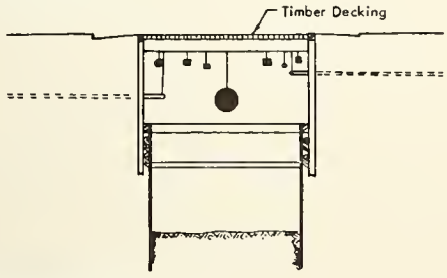
Soldier piles may be driven or they may be augered into the ground to minimize noise. If augered, the space around the piles is usually filled with lean concrete to minimize settlements during excavation.



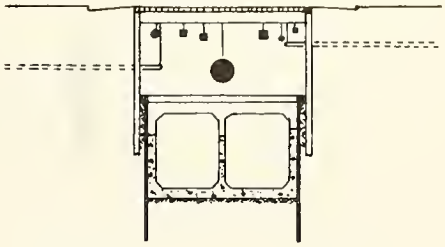
1. Soldier Piles are driven along outer limits of excavation.



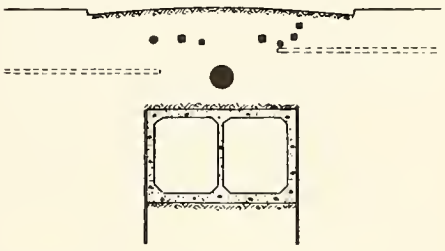
2. Excavation is completed below utilities. Transverse girders are placed across excavation. Utilities are temporarily suspended from girders. Sheet piling is driven from ground water level to bottom limits of excavation.



3. Timber decking is placed over girders for traffic. Subway excavation is completed.



4. Reinforced concrete subway structure is completed.



5. Excavation is backfilled. Utilities are replaced and street pavement is reconstructed.

Figure C-1

STAGES IN CUT-AND-COVER CONSTRUCTION

Precautions taken to preclude settlement of nearby buildings include the prestressing of struts that brace the cut and the fastening of timber lagging to the inside face of piles rather than wedging the lagging behind flanges. Careful construction practices reduce the amount of underpinning necessary.

Driving interlocked steel sheet piling below the ground water table may reduce the inflow of soil where the subway profile drops to this level. Preliminary information indicated that a major portion of the subway work proposed in this report would be of such a nature. Pumping during construction and ground water recharge, therefore, may become advisable.

Waterproofing the subway structure is achieved easily in cut-and-cover construction. In stiff clays, waterproofing membrane is often applied to the outside roof of the structure and extended down the outside of the walls to a point below the upper horizontal construction

joint. In granular soils, membrane may be required on the entire outside surface of the walls and even under the base slab. This sometimes entails widening the trench to permit application of waterproofing material. Waterproofing the roofs of box sections is essential to prevent water from dripping onto tracks and contact rails.

TUNNEL CONSTRUCTION

Tunneling consists of building vertical shafts at intervals along the subway route and excavating tunnels between shafts. In recent years, tunnels have often been excavated by tunneling machines built to order. These are large, complex pieces of equipment composed of power-driven cutting bits or buckets at the leading edge, spoil conveyors, arch-rib setting arms, propelling rams, and auxiliary devices. When air pressure is required to hold back water in permeable soils, machines are sometimes equipped to localize the compressed air at the tunnel face to make air locks and their attendant high costs unnecessary.

Tunnel linings of various materials are currently in use. Single linings may be made of machined cast iron segments, jacked into place, and then bolted and caulked. Precast concrete and fabricated steel liner segments are installed in a similar manner. In poor soil or in granular soil below the ground water table, it is sometimes necessary to use a secondary liner. A primary lining of steel arch ribs and gasketed pressed steel liner plates is set in the tail section of the tunnel shield or tunneling machine. A secondary liner of concrete is placed later. Use of shrinkage compensating cement helps to reduce the amount of ground water seepage into a tunnel. Its use also lengthens the life of the structural concrete and reduces long-term settlement of nearby structures.

CATHODIC PROTECTION

Cathodic protection must be provided for tunnel liner plates, concrete reinforcement bars, and other metal parts which might conduct stray electrical currents. Such cathodic protection was used, for example, on the fabricated steel liner plates of the Callahan Tunnel under Boston Harbor.

The subway structures proposed in this study would lie well below the ground water table in many places. Corrosion of steel or reinforced concrete structures might occur under adverse conditions of soil acidity in the presence of stray electrical currents. It is recommended, therefore, that cathodic protection and other appropriate forms of corrosion control be incorporated in the design of the underground structures.

Appendix D

MECHANICAL FACILITIES IN PROPOSED SUBWAYS

VENTILATION

A necessary requirement for comfort and safety in subways is an adequate ventilation system. The two aspects of this function that must be considered are natural and mechanical ventilation.

Natural ventilation occurs when air is pushed out of the subway tube ahead of a moving train through passages to the surface called vent shafts. A reverse action behind the moving train draws air down into the subway. This continuing circulation of air between subway and surface prevents the accumulation of heat in the subway. Among the sources of heat are the electrical energy used to propel the trains, the body heat of its occupants and such solar effects as external heating of the trains before they enter the subway. The primary source, however, is electrical traction energy, all of which is ultimately dissipated as heat energy. Unless expelled from the subway, the underground atmosphere would become intolerably heated.

Mechanical ventilation is the fan-induced circulation of air through subways. This operation might be the only means of ventilating a deep or sub-aqueous tunnel, but it could also be used in shallow subways during emergencies to purge the tubes of smoke or fumes.

A system of natural ventilation, with a stand-by mechanical system for use during emergencies, would be recommended for subways in Systems I, II and III. Vent shafts would be located at about 500-foot intervals along each track of the subway, each shaft providing a minimum of 100 square feet of gross cross-sectional area for air movement. Additional vent shafts, called blast shafts, having at least twice this capacity would be located immediately before and beyond each station, in each tube, to dissipate the pressure wave effect on persons standing on platforms. Doors should be eliminated from passageways to the surface to aid in the reduction of blast effects at stations.

Emergency mechanical ventilation would be provided by reversible fans located midway between stations, one in each tube. All vent shafts except blast shafts would be equipped with motor-operated louvers. These louvers would close automatically when fans were started to prevent the short-circuit of air through vent shafts. Fans would be operated locally or from a central control panel, with supervisory circuits indicating the condition of operation.

Deep tunnels would require additional study to determine the necessary vent shaft cross-sectional areas and to investigate the need for supplemental mechanical ventilation.

DRAINAGE

Water flows into subways through openings to the surface as well as through cracks in the structure. Seepage inflow may be even more noticeable below the ground water table in sands and gravels, which is the type of soil through which the proposed subways would pass.

All water seeping into subways would be gathered through drains located in vent shafts, in stair wells, and along each track. It would be conducted through ductile iron pipe embedded in concrete to manholes spaced at intervals along the ductile iron main drain located under the subway structure. This water would collect in sumps at low points in the subway, where impeller-type pumps would periodically discharge collected water into City storm sewers overhead.

Pumps would be installed in pairs, with operation on an alternating basis, except during periods of peak inflow when they would operate simultaneously. Such a situation might occur during a flood, fire, or other disaster. Pump operation would be controlled either locally or from a central location, with independent supervisory circuit monitoring.

WATER SUPPLY

Station areas below ground would require water service for a number of uses:

- Agent's drinking and toilet facilities;
- Washing of platform;
- Janitor's closet;
- Fire protection.

Water lines must be insulated in exposed locations.

Dry fire lines would run from surface siamese connections near fire hydrants to convenient locations at platform level below ground. These lines would be charged by the Fire Department only during emergencies and would, therefore, require no insulation.

SANITARY FACILITIES

Since public toilet facilities have been eliminated from consideration, only minimum sanitary facilities for agents would be installed at each station. Venting to the surface and a small sewage ejection unit would meet this need. Discharge would be into City sanitary sewers.

EMERGENCY EXITS

Evacuation of trains in an emergency would require exit stairways alongside each track located approximately midway between stations. These exit structures should have covers easily opened from within but secure from above. The maximum distance from any point in a subway to a station or an emergency exit would be 1,000 feet. A continuous paved walkway along each track would allow access to these exits.

Fire department and civil defense authorities would be afforded access to the subway in emergencies. Removable sections of vent shaft gratings and ladder rungs set in the walls would allow use of the nearest vent shaft for such access.

Appendix E

TRACTION POWER STUDY

I. STUDY OBJECTIVES - CASS

The objectives of this study were to evaluate the complete electrical power requirements, approximate locations of new substations, and, consequently, the optimum system of power distribution for each of the three proposed systems of operational improvements for the Riverside, Beacon Street, Commonwealth Avenue and Huntington Avenue Lines, including the connection between the Riverside Line and the Blue Line to provide a through route between Riverside and Wonderland.

Also included was the evaluation of contact rail, pantograph or trolley pole type power pickup to be used for the various routes involved in this study, together with construction cost estimates for each system.

II. EXISTING TRACTION POWER SYSTEM

The following is a general description of the existing traction power systems for the Green and Blue Lines:

A. Green Lines

- Riverside Line - Fed from Cooks Junction, Coolidge, Oak Square, Newbury, Central, Dewey and North Station substations. Power pickup is by trolley pole from direct suspension overhead contact wire in open sections and from contact wire supported from roof in subway sections. Cooks Junction substation, which is the most westerly substation feeding the line, is located 2.7 miles east of the Riverside Terminal and Yard. This extreme distance, coupled with a concentration of load within the yard during the heavy storage periods, results in a low voltage problem of long standing for this sector.

- Cleveland Circle Line - Fed from Coolidge, Newbury, Central, Dewey and North Station substations. Power pickup is by trolley pole from direct suspension overhead contact wire in open sections and from contact wire supported from roof in subway sections.

- Commonwealth Avenue Line - Fed from Coolidge, Oak Square, Newbury, Central, Dewey and North Station substations. Power pickup is by trolley pole from direct suspension overhead contact wire in open sections and from contact wire supported from roof in subway sections.

- Huntington Avenue Line - Operation of this route between Arborway and Brigham Circle will be discontinued. Consequently, only the remaining section between Brigham Circle and Park Street is considered here. This section is fed from Coolidge, Newbury, Central, Dewey and North Station substations. Power pickup is by trolley pole from direct suspension overhead contact wire in open sections and from contact wire supported from roof in subway sections.

B. Blue Line

- Fed from Dewey, East Boston and Orient Heights substations. Power pickup is from third rail in subway between Bowdoin and Maverick Stations, and by pantograph from catenary in the subway section between Maverick and Airport Stations and in the open between Airport and Wonderland Stations.

- All third rail, overhead contact wire and catenary systems for the above routes are supplemented by heavy feeder cables, either overhead or underground in ducts, and paralleling the track right of way. Some of the feeder runs between substations and track right of way are of considerable length and it would be costly to increase their capacity for load.

- Existing substation AC power is supplied from MBTA generating stations of 13.2 KV, three-phase, 25 Hz. DC traction power system voltage is nominally 600 volts, with a no-load bus voltage of 625 volts and a full load bus voltage of 590 volts. Table E-1 indicates the number and capacity of rectifiers or rotary converters, station capacity and type of operation of the existing substations presently feeding the Green and Blue Lines. All manual and semi-automatic substations require full time attendant service. Also included is the peak power demand on each substation as recorded by the MBTA in 1967.

- Of the existing substations listed in Table E-1, Cooks Junction, Coolidge and Newbury presently serve the Green Lines exclusively. Oak Square substation presently serves the Green Line, the Watertown Car House and Yard and a portion of the Mount Auburn Street trackless trolley. Central substation presently serves the Green Lines and the Orange Line. Dewey substation

Table E-1

EXISTING SUBSTATIONS

SUBSTATION	ROTARY CONVERTER OR RECTIFIER QUANTITY	TYPE	KW	TOTAL STATION CAPACITY KW	1967 PEAK POWER DEMAND KW
Cooks Junction (AS)	2	R	1000	2000	2300
Coolidge (M-SA)	3	C	2000	6000	6100
Oak Square (AS)	2	C	2000	4000	2800
Newbury (AS)	2	R	3000	6000	3600
Central (M)	2	C	3000	6000	4500
Dewey (M)	3	C	3000	9000	5500
North Station (AS)	2	C	3000	6000	3800
East Boston (M-SA)	2	C	1000	4000	1900
	1	C	2000		
Orient Heights (AS)	1	R	1000	2500	2700
	1	R	1500		

C = Rotary Converter
R = Rectifier
(M) = Manual
(SA) = Semi-Automatic
(AS) = Automatic Supervisory

presently serves the Green Lines, Red Line, Orange Line and the Blue Line. North Station substation presently serves the Green Lines and the Orange Line. East Boston and Orient Heights substations presently serve the Blue Line exclusively.

- It is further noted that the 1967 peak power demands shown in Table E-1 for Coolidge, Oak Square, Newbury, Central, Dewey and North Station substations include the loads of the Watertown Line which has since been taken out of service.

III. POWER STUDY CRITERIA

The criteria and basis of these studies to determine the power requirements of the three systems covered in this report are discussed below:

- System Requirements - The ultimate objective of the three systems is to separate the Riverside Line from the other Green Lines and to change it to high-level rapid transit operation connecting it to the existing Blue Line operating between Bowdoin and Wonderland Stations. The changeover would be accomplished in stages utilizing existing and new No. 6 cars and new high-platform rapid transit cars as indicated in Table E-2.

  Since the existing PCC cars will operate only on a nominal 600-volt system without modification, the present distribution system must be retained for their continued use. It was also assumed that the new No. 6 cars which will be intermixed with existing PCC cars in the Central Subway during the early stages, would be designed for operation on a nominal 600-volt distribution system.

  In preliminary power studies for the new Orange and Red Line extensions which were prepared for the MBTA by other consultants, recommendations were made that a DC traction power system with a range of 690-450 volts be adopted as the design criterion for the new lines. This type of system would provide a no-load bus voltage of 690 volts, a full-load bus voltage of 650 volts, and a minimum allowable train voltage of 450 volts. For the purpose of this study, the 690-450 DC traction power system was used as the design criterion for the ultimate Riverside-Wonderland route.

- Power Requirements and Substation Locations - The method used in this study to estimate the peak hour traction power requirements for the various stages of each system is based on the formula:

  $$\text{Average kw/mile/track} = \frac{60 \times (\text{cars/train})\,(\text{kw-hr/car mile})}{(\text{headway in minutes})\,(\text{distribution eff.})}$$

  The "cars/train" and "headway in minutes" for the various routes in each system and stage are as indicated in "Table E-2 - TRAIN CONSIST AND SCHEDULES (Peak Hour)". The "kw-hr/car mile" values for the three types of cars are as shown in the following Table E-3.

Table E-2

TRAIN CONSIST AND SCHEDULES (PEAK HOUR)

SYSTEM	STAGES	LINE	CAR TYPE	CARS PER TRAIN	HEADWAY (MINUTES)
I	1 and 2	Commonwealth Avenue	PCC	3	4.0
I	1 and 2	Beacon Street	PCC	3	4.0
I	1 and 2	Huntington Avenue	PCC	3	4.0
I	1 and 2	Riverside	New high-platform	4	4.0
I	3 and 4	Commonwealth Avenue	New No. 6	3	4.0
I	3 and 4	Beacon Street	No. 6	3	4.0
I	3 and 4	Huntington Avenue	No. 6	3	4.0
I	3 and 4	Riverside	New high-platform	6	1.5 (Ultimate)
II	1 and 2	Commonwealth Avenue	PCC	3	4.0
II	1 and 2	Beacon Street	PCC	3	4.0
II	1 and 2	Huntington Avenue	PCC	3	4.0
II	1 and 2	Riverside	New No. 6	4	4.0
II	3 and 4	Commonwealth Avenue	New No. 6	3	4.0
II	3 and 4	Beacon Street	New No. 6	3	4.0
II	3 and 4	Riverside	New high-platform	6	4.0 (Ultimate)
III	1 and 2	Commonwealth Avenue	PCC	3	4.0
III	1 and 2	Beacon Street	PCC	3	4.0
III	1 and 2	Huntington Avenue	PCC	3	4.0
III	1 and 2	Riverside	New No. 6	4	4.0
III	3 and 4	Commonwealth Avenue	New No. 6	3	4.0
III	3 and 4	Beacon Street	New No. 6	3	4.0
III	3 and 4	Huntington Avenue	New No. 6	3	4.0
III	3 and 4	Riverside	New high-platform	6	1.5 (Ultimate)

Locations of new substations for the interim and ultimate operations of the Riverside Line had to be established before requirements and substation capacities could be determined.

Substation spacing primarily depends upon the minimum allowable voltage drop in the third-rail or overhead power distribution systems. If the maximum bus voltage of substations is 690 volts, no-load, the voltage drop across the substation terminals

Table E-3

KILOWATT HOURS PER CAR MILE

STOPS PER MILE	EXISTING PCC CAR		NEW NO. 6 CAR		NEW HIGH-PLATFORM RAPID TRANSIT CAR	
	INBOUND	OUTBOUND	INBOUND	OUTBOUND	INBOUND	OUTBOUND
1	4.00	3.60	5.25	4.70	5.80	5.20
1-1/2	4.25	3.85	5.80	5.20	6.80	6.10
2	4.50	4.05	6.25	5.60	7.50	6.75
2-1/2	4.75	4.30	6.65	6.00	8.00	7.20
3	5.00	4.50	7.00	6.30	8.50	7.65
3-1/2	5.25	4.75	7.25	6.50	8.95	8.05
4	5.50	4.95	7.50	6.75	9.35	8.40
4-1/2	5.75	5.20	7.70	6.95	9.70	8.75
5	6.00	5.40	7.90	7.10	10.05	9.05
5-1/2	6.25	5.65	8.20	7.35	10.35	9.30
6	6.50	5.85	8.40	7.55	10.65	9.60
6-1/2	6.75	6.10	8.65	7.80	10.90	9.85
7	7.00	6.30	8.90	8.00	11.20	10.10

The above table is based on AM peak hour operations with the outbound values approximately ten percent less than the inbound, due to lower passenger loading. Also included is the energy required for the car auxiliaries.

Maximum accelerating current values for each type car, including auxiliaries, were assumed to be as follows:

Existing PCC car	:	525 amperes
New No. 6 car	:	685 amperes
New high-platform rapid transit car	:	950 amperes

is about 40 volts at full load. The minimum allowable voltage in the third rail or overhead system is 450 volts. The substations must be spaced so that there is no more than a 200-volt drop anywhere in the system. This spacing calculation depends on the resistance of the third-rail or overhead distribution systems, including the running rails plus negative return cables, and the maximum current drawn by a train starting halfway between two substations. It is assumed that if this train starts midway between two substations it will draw, theoretically, one-half of its current requirement from each substation. All new substation locations, regardless of staging, are based on the ultimate operation of six-car rapid transit trains and 90-second headways on the Riverside-Wonderland route. Locations are also based on the utilization of the new and existing third rail or overhead distribution systems with a minimum of supplementary copper.

Rectifying equipment in the new substations was based on "Extra-Heavy-Duty" NEMA Class III traction rating and sized to take care of the peak hour demand load when taking advantage of the rectifiers' 50 percent overload rate for two hours. Another factor considered in determining rectifier capacity is the MBTA requirement that they be sized sufficiently to supply 60 percent of peak load requirement when one of the two or more units is unavailable because of temporary repair or outage.

Studies to determine the adequacy of existing substations and power distribution systems for the new proposed operations of the Commonwealth Avenue, Beacon Street and Huntington Avenue Lines during the various stages are based on the applicable criteria as outlined herein.

Results of the power requirement studies for the various stages of the three Systems covered in this report and based on the foregoing criteria are shown in Tables E-4 through E-15 inclusive.

Loads shown in these tables do not include the present load of the Red and Orange Lines on existing Central, Dewey and North Station substations. It has been assumed that the Red Line load on the existing Dewey substation will have been transferred to the proposed new Dewey substation before the publication of this report. Existing Central, Dewey and North Station substations will be relieved of the Orange Line load upon completion of the new Orange Line route and the new Back Bay and Dewey substations. Until such time, however, these three existing substations have adequate capacity to handle the loads of the existing Orange Line and of the Green Lines during interim stages prior to the initiation of high-platform rapid transit service on the Riverside Line.

Table E-4

SUBSTATION REQUIREMENTS - SYSTEM I - STAGE 1

SUBSTATION	ROUTE LOADS - KW (PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	1735				1735	2(NR)	3000	6000	1160	695
Cooks Junction	1525				1525	2(ER)	1000	2000	1020	610
Hammond Pond	1465				1465	2(NR)	3000	6000	975	585
Reservoir	1630				1630	2(NR)	3000	6000	1090	655
Coolidge	1510	1635	1350	625	5120	3(EC)	2000	6000	3420	2050
Oak Square			1065		1065	2(EC)	2000	4000	710	430
Newbury	1310	805	1005	960	4080	2(ER)	3000	6000	2730	1640
Central	520	230	295	235	1280	2(EC)	3000	6000	855	515
Dewey	180	80	100	95	2745*	3(EC)	3000	9000	1830	1100
North Station	1830	1250	215	90	3380	2(EC)	3000	6000	2260	1360
Totals	11705	4000	4030	2005	24025*					

*Includes 2290 KW for Blue Line

General Notes

(1) One rectifier unit and associated equipment required in addition to the 2-3000 KW units proposed for the Orange Line (Applies to Tables E-6, 7, 10, 11, 14, & 15)

(2) It is assumed that during this stage the proposed Orange, Red and Riverside Lines will not be operating at ultimate headways and that the 4-3000 KW units proposed for the Orange and Red Lines will be adequate to handle the additional load of the temporary Riverside operation to South Station in this stage. (Applies to Tables E-6 and E-10.)

(3) Two rectifier units and associated equipment required in addition to the 4-3000 KW units proposed for the Orange and Red Lines. (Applies to Tables E-7, 11, 14, & 15)

Legend

(NR) New Rectifier Units
(ER) Existing Rectifier Units
(EC) Existing Rotary Converter Units

Table E-5

SUBSTATION REQUIREMENTS - SYSTEM I - STAGE 2

SUBSTATION	ROUTE LOADS - KW(PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	1735				1735	2(NR)	3000	6000	1160	695
Cooks Junction	1525				1525	2(ER)	1000	2000	1020	610
Hammond Pond	1465				1465	2(NR)	3000	6000	975	585
Reservoir	1630				1630	2(NR)	3000	6000	1090	655
Coolidge	1395	1635	1350	625	5005	3(EC)	2000	6000	3340	2000
Oak Square			1065		1065	2(EC)	2000	4000	710	430
Newbury	1330	805	1005	960	4100	2(ER)	3000	6000	2740	1650
Central	700	230	290	235	1455	2(EC)	3000	6000	970	585
Dewey	420	80	105	90	2985*	3(EC)	3000	9000	1990	1200
North Station		1135	220	90	1445	2(EC)	3000	6000	965	580
Totals	10200	3885	4035	2000	22410					

*Includes 2290 KW for Blue Line

Table E-6

SUBSTATION REQUIREMENTS - SYSTEM I - STAGE 3

SUBSTATION	ROUTE LOADS - KW (PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	6580				6580	2(NR)	3000	6000	4385	2630
Cooks Junction	7450				7450	2(NR)	3000	6000	4965	2980
Hammond Pond	6955				6955	2(NR)	3000	6000	4635	2780
Reservoir	6690				6690	2(NR)	3000	6000	4460	2675
Brookline Village	5605				5605	2(NR)	3000	6000	3740	2245
Fenway Park	5280				5280	2(NR)	3000	6000	3520	2115
Back Bay	5645				5645 (1)	1(NR)	3000	3000	3765	2260
New Dewey	2735				2735 (2)				1825	1095
Coolidge		2280	1695	790	4765	3(EC)	2000	6000	3180	1910
Oak Square			1285		1285	2(EC)	2000	4000	860	515
Newbury		1375	1450	1360	4185	2(ER)	3000	6000	2795	1675
Central		440	445	410	1295	2(EC)	3000	6000	865	520
Existing Dewey		150	150	155	2745*	3(EC)	3000	9000	1830	1100
North Station		1030	675	320	2025	2(EC)	3000	6000	1365	820
Totals	46,940	5275	5700	3035	63240					

* Includes 2290 KW for Blue Line

For Notes (1) and (2) See Table E-4

Table E-7

SUBSTATION REQUIREMENTS - SYSTEM I - STAGE 4

SUBSTATION	ROUTE LOADS - KW(PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	6580				6580	2(NR)	3000	6000	4385	2630
Cooks Junction	7450				7450	2(NR)	3000	6000	4965	2980
Hammond Pond	6955				6955	2(NR)	3000	6000	4635	2780
Reservoir	6690				6690	2(NR)	3000	6000	4460	2675
Brookline Village	5605				5605	2(NR)	3000	6000	3740	2245
Fenway Park	5280				5280	2(NR)	3000	6000	3520	2115
Back Bay	4830				4830 (1)	1(NR)	3000	3000	3220	1935
New Dewey	9145				9145 (3)	2(NR)	3000	6000	6090	3660
Airport	6400				6400	2(NR)	3000	6000	4270	2560
Orient Heights	6950				6950	2(NR)	3000	6000	4640	2785
Wonderland	4485				4485	2(NR)	2000	4000	2990	1790
Coolidge		2280	1695	790	4765	3(EC)	2000	6000	3180	1910
Oak Square			1285		1285	2(EC)	2000	4000	860	515
Newbury		1375	1450	1360	4185	2(ER)	3000	6000	2795	1675
Central		440	445	410	1295	2(EC)	3000	6000	865	520
Existing Dewey		150	150	155	455	3(EC)	3000	9000	305	185
North Station		1030	675	320	2025	2(EC)	3000	6000	1365	820
Totals	70,370	5275	5700	3035	84,380					

For Notes (1) and (3) See Table

Table E-8

SUBSTATION REQUIREMENTS - SYSTEM II - STAGE 1

SUBSTATION	ROUTE LOADS - KW(PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	1735				1735	2(NR)	3000	6000	1160	695
Cooks Junction	1525				1525	2(ER)	1000	2000	1020	610
Hammond Pond	1465				1465	2(NR)	3000	6000	975	585
Reservoir	1630				1630	2(NR)	3000	6000	1090	655
Coolidge	1510	1635	1350	625	5120	3(EC)	2000	6000	3420	2050
Oak Square			1065		1065	2(EC)	2000	4000	710	430
Newbury	1310	805	1005	960	4080	2(ER)	3000	6000	2730	1640
Central	520	230	295	235	1280	2(EC)	3000	6000	855	515
Dewey	180	80	100	95	2745*	3(EC)	3000	9000	1830	1100
North Station	1830	1250	215	90	3380	2(EC)	3000	6000	2260	1360
Totals	11705	4000	4030	2005	24025*					

*Includes 2290 KW for Blue Line

Table E-9

SUBSTATION REQUIREMENTS - SYSTEM II - STAGE 2

SUBSTATION	ROUTE LOADS - KW(PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	1735				1735	2(NR)	3000	6000	1160	695
Cooks Junction	1525				1525	2(ER)	1000	2000	1020	610
Hammond Pond	1465				1465	2(NR)	3000	6000	975	585
Reservoir	1630				1630	2(NR)	3000	6000	1090	655
Coolidge	1510	1635	1350	510	5005	3(EC)	2000	6000	3340	2000
Oak Square			1065		1065	2(EC)	2000	4000	710	430
Newbury	1310	805	1005	720	3840	2(ER)	3000	6000	2560	1540
Central	520	230	295	300	1345	2(EC)	3000	6000	900	540
Dewey	180	80	100	300	2950*	3(EC)	3000	9000	1970	1180
North Station	1830	1250	215		3295	2(EC)	3000	6000	2200	1320
Totals	11,705	4000	4030	1830	23855					

*Includes 2290 KW for Blue Line

Table E-10

SUBSTATION REQUIREMENTS - SYSTEM II - STAGE 3

SUBSTATION	ROUTE LOADS - KW (PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	6580				6580	2(NR)	3000	6000	4385	2630
Cooks Junction	7450				7450	2(NR)	3000	6000	4965	2980
Hammond Pond	6955				6955	2(NR)	3000	6000	4635	2780
Reservoir	6690				6690	2(NR)	3000	6000	4460	2675
Brookline Village	5605				5605	2(NR)	3000	6000	3740	2245
Ruggles Street	5080				5080	2(NR)	3000	6000	3390	2035
Back Bay	5490				5490 (1)	1(NR)	3000	3000	3660	2200
New Dewey	2735				2735 (2)				1825	1095
Coolidge		2280	1695		3975	3(EC)	2000	6000	2650	1590
Oak Square			1285		1285	2(EC)	2000	4000	860	515
Newbury		1375	1450		2825	2(ER)	3000	6000	1885	1130
Central		440	445		885	2(EC)	3000	6000	590	355
Existing Dewey		150	150		2590*	3(EC)	3000	9000	1730	1035
North Station		1030	675		1705	2(EC)	3000	6000	1140	685
Totals	46,585	5275	5700		59,850					

*Includes 2290 KW for Blue Line

For Notes (1) and (2) See Table E-4

Table E-11

SUBSTATION REQUIREMENTS - SYSTEM II - STAGE 4

SUBSTATION	ROUTE LOADS - KW (PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	6580				6580	2(NR)	3000	6000	4385	2630
Cooks Junction	7450				7450	2(NR)	3000	6000	4965	2980
Hammond Pond	6955				6955	2(NR)	3000	6000	4635	2780
Reservoir	6690				6690	2(NR)	3000	6000	4460	2675
Brookline Village	5605				5605	2(NR)	3000	6000	3740	2245
Ruggles Street	5080				5080	2(NR)	3000	6000	3390	2035
Back Bay	4680				4680 (1)	1(NR)	3000	3000	3125	1875
New Dewey	9145				9145 (3)	2(NR)	3000	6000	6090	3660
Airport	6400				6400	2(NR)	3000	6000	4270	2560
Orient Heights	6950				6950	2(NR)	3000	6000	4640	2785
Wonderland	4485				4485	2(NR)	2000	4000	2990	1790
Coolidge		2280	1695		3975	3(EC)	2000	6000	2650	1590
Oak Square			1285		1285	2(EC)	2000	4000	860	515
Newbury		1375	1450		2825	2(ER)	3000	6000	1885	1130
Central		440	445		885	2(EC)	3000	6000	590	355
Existing Dewey		150	150		300	3(EC)	3000	9000	200	120
North Station		1030	675		1705	2(EC)	3000	6000	1140	685
Totals	70,020	5275	5700		80,995					

For Notes (1) and (3) See Table E-4

Table E-12

SUBSTATION REQUIREMENTS - SYSTEM III - STAGE 1

SUBSTATION	ROUTE LOADS - KW (PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	1735				1735	2(NR)	3000	6000	1160	695
Cooks Junction	1525				1525	2(ER)	1000	2000	1020	610
Hammond Pond	1465				1465	2(NR)	3000	6000	975	585
Reservoir	1630				1630	2(NR)	3000	6000	1090	655
Coolidge	1510	1635	1350	625	5120	3(EC)	2000	6000	3420	2050
Oak Square			1065		1065	2(EC)	2000	4000	710	430
Newbury	1310	805	1005	960	4080	2(ER)	3000	6000	2730	1640
Central	520	230	295	235	1280	2(EC)	3000	6000	855	515
Dewey	180	80	100	95	2745*	3(EC)	3000	9000	1830	1100
North Station	1830	1250	215	90	3380	2(EC)	3000	6000	2260	1360
Totals	11705	4000	4030	2005	24025*					

*Includes 2290 KW for Blue Line

Table E-13

SUBSTATION REQUIREMENTS - SYSTEM III - STAGE 2

SUBSTATION	ROUTE LOADS - KW(PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	1735				1735	2(NR)	3000	6000	1160	695
Cooks Junction	1525				1525	2(ER)	1000	2000	1020	610
Hammond Pond	1465				1465	2(NR)	3000	6000	975	585
Reservoir	1630				1630	2(NR)	3000	6000	1090	655
Coolidge	1510	1385	1350	510	4755	3(EC)	2000	6000	3175	1905
Oak Square			1065		1065	2(EC)	2000	4000	710	430
Newbury	1310	130	420	720	2580	2(ER)	3000	6000	1720	1030
Central	520			300	820	2(EC)	3000	6000	545	330
Dewey	180			300	2770*	3(EC)	3000	9000	1850	1110
North Station	2130				2130	2(EC)	3000	6000	1420	850
Totals	12,005	1515	2835	1830	20,475*					

*Includes 2290 KW for Blue Line

Table E-14

SUBSTATION REQUIREMENTS - SYSTEM III - STAGE 3

SUBSTATION	ROUTE LOADS - KW (PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	6580				6580	2(NR)	3000	6000	4385	2630
Cooks Junction	7450				7450	2(NR)	3000	6000	4965	2980
Hammond Pond	6955				6955	2(NR)	3000	6000	4635	2780
Reservoir	6690				6690	2(NR)	3000	6000	4460	2675
Brookline Village	5415				5415	2(NR)	3000	6000	3610	2165
Fenway Park	5805				5805	2(NR)	3000	6000	3875	2325
Back Bay	5730				5730 (1)	1(NR)	3000	3000	3825	2300
New Dewey	9290				9290 (3)	2(NR)	3000	6000	6200	3720
Airport	6305				6305	2(NR)	3000	6000	4210	2525
Orient Heights	6950				6950	2(NR)	3000	6000	4640	2785
Wonderland	4485				4485	2(NR)	2000	4000	2990	1790
Coolidge		2080	1695	425	4200	3(EC)	2000	6000	2800	1680
Oak Square			1285		1285	2(EC)	2000	4000	860	515
Newbury		395	590	1010	1995	2(ER)	3000	6000	1330	800
Central				380	380	2(EC)	3000	6000	255	155
Existing Dewey				115	115	3(EC)	3000	9000	80	50
North Station				935	935	2(EC)	3000	6000	625	375
Totals	71,655	2475	3570	2865	80,565					

For Notes (1) and (3) See Table E-4

Table E-15

SUBSTATION REQUIREMENTS - SYSTEM III - STAGE 4

SUBSTATION	ROUTE LOADS - KW(PEAK HOUR)				TOTAL SUBSTATION LOADS - KW	NEW OR EXISTING ROTARY CONVERTERS OR RECTIFIERS			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
	RIVERSIDE	CLEVELAND CIRCLE	BOSTON COLLEGE	HUNTINGTON AVENUE		QUANTITY	KW	TOTAL KW		
Woodland	6580				6580	2(NR)	3000	6000	4385	2630
Cooks Junction	7450				7450	2(NR)	3000	6000	4965	2980
Hammond Pond	6955				6955	2(NR)	3000	6000	4635	2780
Reservoir	6690				6690	2(NR)	3000	6000	4460	2675
Brookline Village	5415				5415	2(NR)	3000	6000	3610	2165
Fenway Park	5805				5805	2(NR)	3000	6000	3875	2325
Back Bay	5730				5730 (1)	1(NR)	3000	3000	3825	2300
New Dewey	9290				9290 (3)	2(NR)	3000	6000	6200	3720
Airport	6305				6305	2(NR)	3000	6000	4210	2525
Orient Heights	6950				6950	2(NR)	3000	6000	4640	2785
Wonderland	4485				4485	2(NR)	2000	4000	2990	1790
Coolidge		2080	1695	795	4570	3(EC)	2000	6000	3050	1830
Oak Square			1285		1285	2(EC)	2000	4000	860	515
Newbury		395	590	1195	2180	2(ER)	3000	6000	1455	875
Central				380	380	2(EC)	3000	6000	255	155
Existing Dewey				115	115	3(EC)	3000	9000	80	50
North Station				935	935	2(EC)	3000	6000	625	375
Totals	71,655	2475	3570	3420	81,120					

For Notes (1) and (3) See Table E-4

IV. NEW SUBSTATIONS

New substations for the proposed high-platform rapid transit operation on the Riverside-Wonderland route would be unattended, with remote control and supervision of equipment from a central dispatching station. Each station would be ventilated.

The power for the proposed system would be 690 volts DC, no-load, which would be converted at the substations from various public utility 13.8 KV AC power sources, which would be provided from their underground or overhead distribution systems. Two independent power sources are proposed at each substation in order to maintain service in case of a sudden failure occurring on any one utility source. Design capacities of the substations would be either two 2,000 or two 3,000 KW, as required.

All relays would be coordinated to provide selective tripping of the circuit breakers.

Each substation would have batteries to provide DC power for switchgear control, substation emergency lights and the supervisory control system.

Equipment would be of the type and rating outlined in the sample specifications contained in the following paragraphs.

A. Switchgear

The AC switchgear section shall have five air circuit breaker compartments, two incoming line compartments, two utility metering compartments and two auxiliary compartments complete with potential and control power transformer. Each switchgear unit will include the necessary protective relays for railway service. The high voltage switchgear will be indoor, metal-clad equipment with removable, draw-out, stored-energy-operated breakers. The installations will be rated at 13,800 volts, three-phase, 1,200-amperes continuous, 500,000 KVA interrupting, and 40,000-amperes momentary.

Normally, both incoming breakers will be closed and the tie breaker will be open. The tie breaker can only be closed with one incoming line breaker fully open. Automatic controls will transfer the connected load to a single incoming line when the voltage in the other line decreases below the relay settings. Two 25 KVA or larger control power transformers with draw-out type current limiting fuses, one connected to each bus, will supply substation AC power and signal power.

Two metering compartments, one in each bus lineup, will be provided for power company instrument transformers and metering equip-

ment. Connections will be on the load side of each incoming line breaker in accordance with metering standards of the utility company.

The additional power equipment to be installed at each substation will consist of the following:

- Two rectifier transformers.
- Two AC bus runs (15 KV) between AC switchgear and rectifier transformer. (This might be 15 KV cable.)
- Two bus runs between rectifier transformer and rectifier.
- Two rectifiers. (Rectifier and transformer might be one unit.)
- One DC switchgear, complete with two cathode breakers and as many feeder breakers as required, completely equipped with automatic reclosing.

The DC switchgear will be draw-out, high-speed or semi-high-speed, 125-volt DC solenoid-operated, complete with cathode breakers with reverse current trip attachment and feeder breakers with instantaneous overcurrent trip attachment and load measuring reclosing equipment. They will be mounted in individual units complete with associated control equipment on front panels.

A negative bus with two main negative disconnect switches and the necessary amount of drainage contactors for gas, electric and telephone companies shall be furnished to protect against stray currents.

Depending on the location of the substation, the AC and DC switchgear can be installed in a building or in a weatherproof shelter housing furnished by the switchgear manufacturer.

B. Rectifier Transformer and Rectifier

The rectifier transformer, rectifier, and cathode breaker will be an integral unit, have an overall voltage regulation of about six percent, be rated in accordance with "Extra-Heavy-Duty" NEMA Class III traction rating, and be suitable for parallel operation with other similar units. Each transformer-rectifier unit will be so designed as to deliver 12-pulse DC output from the substation DC bus.

Rectifier transformers will be oil-filled, self-cooled, 60-cycle, 13.8 KV, each having double secondary, one wye and one delta, for six-phase output to the rectifier. In order to provide for the changing of the full load voltage from the initial 590-volt system to the ultimate 650-volt system, a nine-point no-load tap changer will be provided.

On position three, with normal 13.8 KV supply, the full load voltage will be 590 volts with two 2 1/2 percent taps below. On position seven with normal 13.8 KV supply, the full-load voltage will be 650 volts with two 2 1/2 percent taps above and two 2 1/2 percent taps below. Standard protection will be provided for surges, high temperature, liquid levels and pressure.

The rectifiers will be the solid state, silicon diode, six-phase, 12-pulse, double way type with convection cooling. Following rated full-load operation, the rectifier units will be designed to withstand 150 percent rated load for two hours, then 300 percent rated load for five minutes, then 450 percent rated load for 15 seconds.

C. Supervisory Control

A solid state supervisory control system at each substation will allow equipment supervision and control from the master station located in the Dewey Square Control Center. A remote supervisory station will be housed in a free-standing panel at each substation and connected to the master station in the Control Center by means of pilot wires in the signal cables on the Authority's property. The supervisory control system will also provide telephone communication between each substation and the Dewey Square Control Center.

Each control panel of the substation will be equipped with necessary points for control and indication, necessary points for alarm and indication, necessary points for telemetering and one point for telephone.

Remotely-operated circuit breakers will have a "supervisory-local" switch which, in the "local" position, will allow manual control at the breaker and prevent supervisory control.

The supervisory control equipment will permit remote operation, such as closing and tripping of all breakers (AC or DC) as set up and required. The rectifier transformer and rectifier including AC breaker and cathode breaker will be operated as a unit through supervisory control. It will show the status of all remote equipment by indication lights and will indicate to the dispatcher when trouble occurs by bell and flashing red or green lights.

D. Batteries

Pasted-plate, lead-calcium-type batteries will be used throughout. Each battery system will have a static type charger.

The control power batteries will be 125-volt, 60-cell-type designed to close and trip the electrically-operated circuit breakers. The batteries will also provide emergency substation lighting for a minimum

period of eight hours following loss of regular power. The battery sizes, based on the eight-hour discharge rate, will be between 150 and 200 ampere hours.

The supervisory control equipment at the substation will be connected to its own battery.

V. POWER SUPPLY AND DISTRIBUTION

A. AC Power Supply

Dual power supplies will be used at each new substation to provide a reliable source of traction power. The power system will be connected to two full-rated, independent incoming AC lines, originating from separate buses at the supplying utility. Both lines will normally be connected to the substation sectionalized AC bus, with each supplying one-half the total load. In the event of the failure of one line, the other will be required to carry the entire load.

The two proposed lines should be exclusively for MBTA use. If experience with the transit load shows that other customers can be connected, the utility company might use one or both of the lines for such services. However, the connected load will be limited so that a single incoming line will be capable of supplying the entire MBTA requirement.

B. Third-Rail Construction

All new third rail construction will be of the overrunning type, supported on insulators. It will be 150-pound steel with an electrical resistance ratio to copper of 6.85 to one. In addition to being sectionalized at the substations, the third rail will also be sectionalized within limits of passenger stations to allow de-energizing during an emergency. Supplemental copper cables will be provided where necessary to meet the voltage regulation requirements.

Existing Blue Line third rail system in the subway between Bowdoin and Maverick Stations, including supplemental copper cables, will be retained. Additional supplemental copper will be added where necessary to meet voltage regulation requirements.

C. Catenary Construction in Subway

Catenary construction within the subway sections shall be in accordance with MBTA Drawing No. B-15626 A. This system consists of a New Haven section trolley wire used as messenger, supported by trolley clamps and born hangers mounted on a wood block and fastened to the roof of the subway structure at ten-foot spacing for both tangent

and curves. A No. 4/0 grooved trolley wire would be supported from the messenger by means of a short hanger located midway between messenger supports. On curves a contact wire pullover would be provided at each messenger support. Supplementary copper cable would be installed as required for current-carrying capacity and voltage regulation.

D. Catenary Construction At-Grade

New catenary construction and the conversion of the present Riverside direct suspension overhead to a catenary system shall comply with the following:

- Supporting Structures - Catenary cross-span-type support structures, including line hardware items, shall be in accordance with MBTA Drawing Nos. W-13762-A and W-13763-A for tangent track, and W-13764-B for curved track. Support poles for new catenary construction and those required for replacement in the conversion work shall be wide flange sections, selected of such strength that normal applied transverse loading shall not exceed 67 percent of the load which will stress support to its elastic limit. Loading to be based on NESC heavy loading district (H). Existing Riverside direct suspension system support poles, not removed in the track relocation work, will be utilized to the greatest extent possible.

  New catenary supports shall be spaced between 120 and 150 feet apart on tangent. Curve spacing shall be as nearly as practical in accordance with the following:

Radius of Curve (Ft.)	Structure Spacing (Ft.)
40-500	50
500-800	75
Above 800	100

  Distance from face of support poles to overhang of cars shall not be less than two feet at any location.

  Dead end structures shall be in accordance with MBTA Drawing No. 13934-A. Loading on anchors in earth shall be taken as an unbalanced pull equal to the combined tension of all conductors and wires based on NESC heavy loading district (H).

  Structure poles shall be set in 3,000 psi concrete to provide adequate and safe bearing for applied loads. Top of footing shall extend above grade and shall slope up to the poles at a slight angle for drainage.

- Messenger and Contact Wires - Messenger shall be Copper-weld-Copper conductor with equivalent conductance of 350,000 CM copper. Contact wire to be No. 4/0 AWG grooved, bronze trolley wire supported from messenger by insulated hangers suitable for both trolley pole and pantograph current collection. Contact wires to be tensioned to 2,500 pounds at 60 degrees F. with a nominal height of 16 feet above top of rail except under bridges and passenger station canopies, where maximum available height should be utilized.

  Exposed steel of bridges above messengers shall be protected with non-hygroscopic insulating material extending at least six inches each side of centerline of messenger and not less than 12 inches beyond steel in line with messenger.

  Adequate means shall be provided to prevent inadvertent or deliberate contact with overhead wires by the public. Solid or mesh fencing at sides and approaches to bridges may be necessary.

  Where contact wire is to be installed more than six inches below nominal height of 16 feet when running under bridges, passenger station canopies or other structures, the gradient from the lower height to the nominal height shall not be greater than two percent.

  Construction at crossovers shall be in accordance with MBTA Drawing No. C-13941-A.

  Catenary sidefeed from overhead feeders and equalizer connections between messenger and contact wire shall be in accordance with MBTA Drawing No. W-13782-A. Valve, plus series gap lightning arresters shall be located on structures where sidefeeds occur with shortest possible connection to point where sidefeed is connected to feeder. Ground wire for lightning arresters shall be No. 4 AWG solid copper conductor securely fastened to back of structure support pole and connected to a Copperweld rod driven into ground close to structure footing.

VI. STUDY OBJECTIVES - WESTERN CORRIDOR

The objectives of this study were to evaluate the complete electrical power requirements, approximate locations of new substations and, consequently, the optimum system of power distribution for each of the four alternative methods of operations for the Western Corridor Route, which are outlined below:

1. High-level rapid transit operation between Fenway Park Junction and Riverside terminal with six-car trains at three-minute headways during the peak hours.

2. High-level rapid transit operation between Riverside terminal and Framingham with six-car trains at six-minute headways during the peak hours.

3. High-level rapid transit operation from Fenway Park Junction to Riverside Junction with six-car trains at three-minute headways. Alternate trains would terminate at Riverside with the remaining trains continuing on to Framingham on six-minute headways.

4. High-level rapid transit operation from Fenway Park Junction to Riverside Junction with six-car trains at one and one-half minute headway. Alternate trains would terminate at Riverside with the remaining trains continuing on to Framingham on three-minute headways.

Also included was the evaluation of electrical power requirement, substation location and power distribution for the Needham Extension from Cooks Junction on the Riverside Line to Needham Heights. This was to be based on high-level rapid transit operation with six-car trains at three-minute headways.

VII. POWER STUDY CRITERIA - WESTERN CORRIDOR

The criteria and basis of these studies to determine the power requirements for the four alternative methods of operations of the Western Corridor Route and the Needham Extension are as outlined below.

- System Requirements - Train consist and peak hour operating schedules are as indicated previously under VI. - Study Objectives.

  Since the Western Corridor and Needham Extension routes will be interconnected with the Riverside Line, the design criteria for the DC Traction Power System for these routes must be the same as those used for the Riverside study. This system has a voltage range of 690-450 volts which provides a no-load bus voltage of 690 volts, a full-load bus voltage of 650 volts and a minimum allowable train voltage of 450 volts.

- Power Requirements and Substation Locations - The method used in this study to estimate the peak hour traction power requirements is based on the formula:

  Average kw/mile/track =

  $$\frac{60 \times (\text{cars/train})\ (\text{kw-hr/car mile})}{(\text{headway in minutes})\ (\text{distribution eff.})}$$

The "kw-hr/car mile" values for the high-level rapid transit type car are as tabulated below:

Stops per Mile	Kilowatt Hours per Car Mile: Inbound Track	Kilowatt Hours per Car Mile: Outbound Track
1/2	5.00	4.50
1	5.80	5.20
1 1/2	6.80	6.10
2	7.50	6.75
2 1/2	8.00	7.20
3	8.50	7.65
3 1/2	8.95	8.05

The above values are based on a.m. peak hour operations with the outbound values approximately 10 percent less than the inbound due to lower passenger loading. Included is the energy required for the car auxiliaries.

Maximum accelerating current value for the high-level rapid transit type car was assumed to be 950 amperes.

Locations of new substations for the Western Corridor and the Needham Extension must be established before power requirements and substation capacities can be determined.

Substation spacing primarily depends upon the maximum allowable voltage drop in the distribution system. For the purpose of this study, a catenary distribution system for the Western Corridor Route and the Needham Extension is used in order for it to be compatible with the catenary system proposed for the Riverside Line. With a full-load substation bus voltage of 650 volts and a minimum allowable voltage of 450 volts, the substations must be spaced so that there is no more than a 200-volt drop anywhere in the system. This spacing calculation depends on the loop resistance of the overhead distribution system, the running rails plus negative return cables, and the maximum current drawn by a train starting halfway between two substations. It is assumed that if this train starts midway between two substations, it will draw, theoretically, one-half of its current requirement from each substation.

Rectifying equipment in the new substations was based on extra-heavy-duty NEMA Class III traction rating and sized to take care of the peak-hour demand load when taking advantage of the rectifier's 50 percent overload rate for two hours. Another factor

considered in determining rectifier capacity is the MBTA requirement that they be sized sufficiently to supply 60 percent peak-load requirement when one of the two or more is unavailable because of temporary repair or outage.

Results of the power requirement studies for the four alternative methods of operations on the proposed Western Corridor route, based on the foregoing criteria, are shown in Tables E-16 and E-17.

Table E-16

SUBSTATION REQUIREMENTS - WESTERN CORRIDOR

(See Note 1)

SUBSTATION	TOTAL SUBSTATION LOAD - KW (PEAK HOUR)	PROPOSED RECTIFIER CAPACITY			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
		QUANTITY	KW	TOTAL KW		
East Framingham	1140	2	1000	2000	760	455
Fisk Pond	1365	2	1000	2000	910	545
Morses Pond	1270	2	1000	2000	850	510
Wellesley Hills	1270	2	1000	2000	850	510
Lower Falls	1705	2	1000	2000	1140	685
West Newton	2645	2	1500	3000	1765	1060
Newton	2545	2	1500	3000	1700	1020
North Brighton	2545	2	1500	3000	1700	1020
Fenway Park*	1270				850	510

Note 1. Based on 6-minute headways between East Framingham and Riverside Junction and 3-minute headways between Riverside Junction & Fenway Park Junction.

*Fenway Park substation as proposed for the new Riverside Route under Systems I and III, or a separate substation for the Western Corridor Route under System II. Load shown is for Western Corridor Route west of substation only. Individual or combined loads of the Western Corridor and Riverside routes east of the Fenway Park substation would be dependent on the proposed combination of operations.

For the Needham Extension, a new substation consisting of two 1,500-kw rectifier units would be required at Needham Heights.

New substation requirements, AC power supply, and catenary construction proposed for the Western Corridor Route and the Needham Extension shall be as outlined in the power study for the three proposed systems of operational improvements for the Riverside, Beacon Street, Commonwealth Avenue and Huntington Avenue branches of the present Green Line System.

Table E-17

SUBSTATION REQUIREMENTS - WESTERN CORRIDOR

(See Note 1)

SUBSTATION	TOTAL SUBSTATION LOAD - KW (PEAK HOUR)	PROPOSED RECTIFIER CAPACITY			CAPACITY REQUIRED UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS	CAPACITY REQUIRED TO SUPPLY 60 PERCENT OF DEMAND WITH ONE UNIT OUT, AND UTILIZING 50 PERCENT OVERLOAD RATE FOR TWO HOURS
		QUANTITY	KW	TOTAL KW		
East Framingham	2280	2	1000	2000	1520	910
Fisk Pond	2730	2	1500	3000	1820	1090
Morses Pond	2540	2	1500	3000	1700	1020
Wellesley Hills	2540	2	1500	3000	1700	1020
Lower Falls	3410	2	1500	3000	2280	1370
West Newton	5290	2	3000	6000	3530	2120
Newton	5090	2	3000	6000	3400	2040
North Brighton	5090	2	3000	6000	3400	2040
Fenway Park*	2540				1700	1020

Note 1. Based on 3-minute headways between East Framingham and Riverside Junction and 1-1/2-minute headways between Riverside Junction & Fenway Park Junction

*See Table No. E-16

Appendix F

SIGNAL DATA

COPLEY JUNCTION IMPROVEMENTS

The Green Line between Copley Junction and Boylston Station is the most congested portion of the Central Subway system. Long delays occur in that section during peak periods. Delays are caused by the physical conflict between vehicles on different routes, and by the Operating Rules, in combination with the signaling system at Copley Junction, the at-grade point where the Huntington Avenue Subway joins the Boylston Street Subway.

Although delays are also occasioned by station loading characteristics, this section of the report will consider only the Copley Junction problems.

Figure F-1 shows the existing track and signaling layout; Figure F-2 a suggested modified layout. The following descriptions refer to both diagrams.

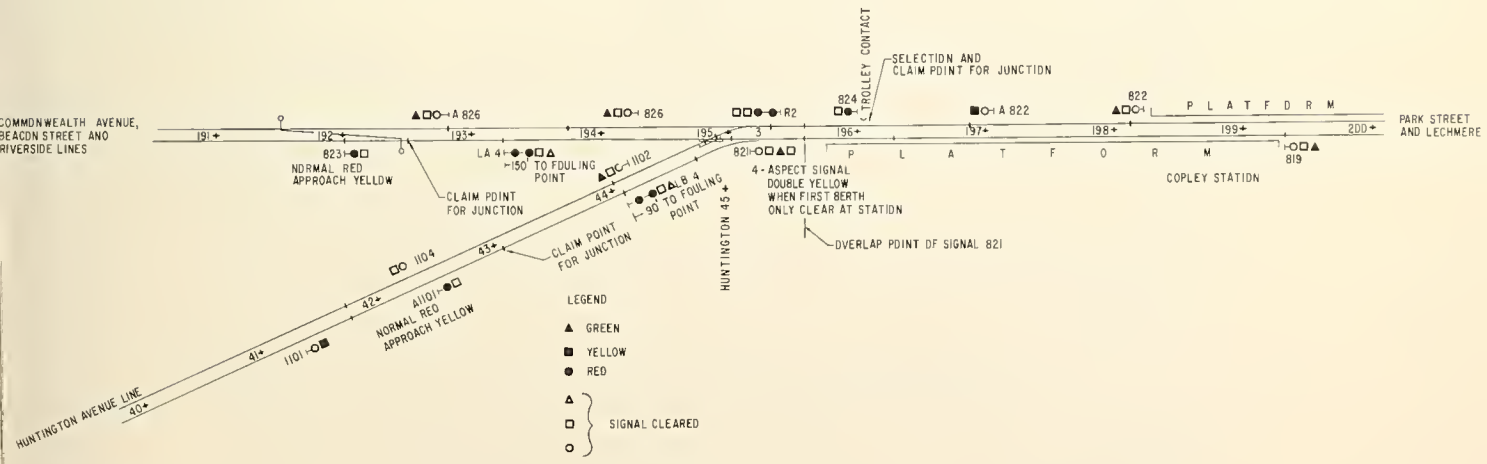


Figure F-1

EXISTING SIGNALS AT COPLEY JUNCTION

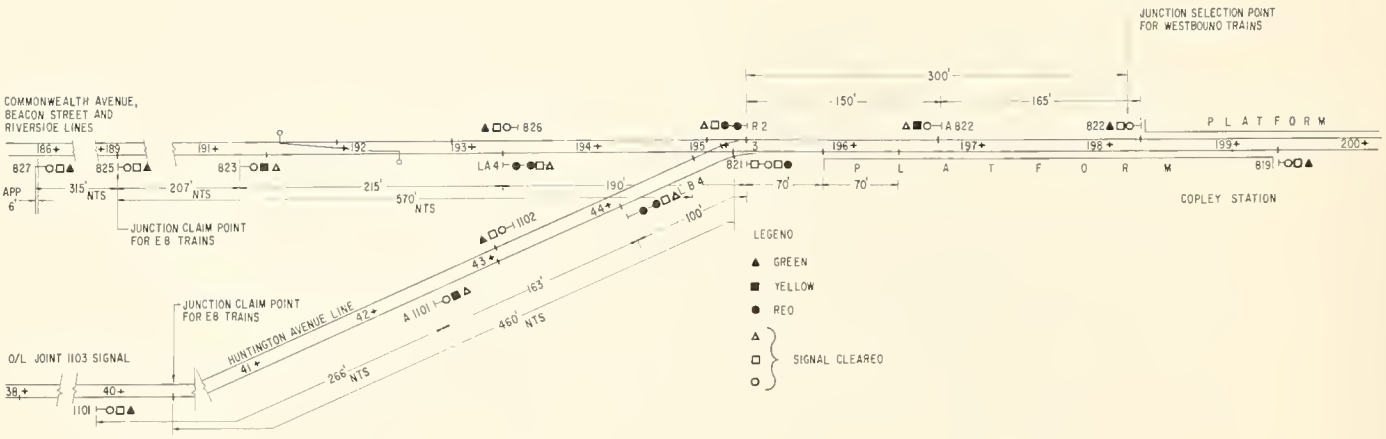


Figure F-2

PROPOSED SIGNAL MODIFICATIONS AT COPLEY JUNCTION

Existing Operations

Service in the Boylston Street Subway is provided by PCC surface type cars, in single, two-or three-unit train consists. Operation is controlled automatically through track circuits by three-aspect color light signals (red, yellow, and green) at trackside, designed for 30-second minimum headways between trains. There are no devices to enforce obedience to stop-aspect signals.

Automatic interlocking is provided at this junction. The facing (divergent) and trailing (convergent) switches each are fitted with a power switch machine and circuit controller to set the junction for the desired movement, to lock the switch in the proper position, and to detect that the switch tongue is correctly set. Signals protecting movements over the junction are of the interlocking type normally displaying a "stop and stay" (red-over-red) aspect, indicating that they cannot be passed without following special procedures under the Operating Rules.

The interlocking equipment ensures that conflicting movements cannot occur. A converging movement is controlled to approximately six miles per hour by timed approach to the rear signal (823 or A1101 in Figure F-1 and then allowed to proceed under a yellow aspect to the home signal (LA4 or LB4). At this point the approaching train enters a claim to the junction. If no conflicting movements have been authorized and if the route is clear to the overlap point of the signal ahead (821), the switches will set and the home signal will display yellow or green depending on conditions.

The procedure at facing switches is designed to be compatible with the operation on surface lines where there is no signal protection. Care and discipline are necessary when a car rounds a sharp turnout to prevent collision with vehicles in an opposing traffic stream in the event a switch should fail to set for the straight route. The car operator selects the required route with the help of a trolley wire contactor unit so placed that the unit is in circuit when the front of the car is approximately 40 feet from the switch. If the trolley pole collector moves over the contact wire contactor while the car motor circuit is energized, a call for the right-hand route is registered; when the circuit is de-energized, a call for the left-hand route is registered. The rules require a stop to be made before operating over the switch to ensure that it is in the desired position. Where signal protection is provided, as at Copley Junction, such a stop is unnecessary, since the interlocking will prevent the signal from showing "proceed" unless the switch is locked in the correct position.

When a conflict occurs at an automatic interlocking, the equipment operates on a first-come, first-served basis. The locations at which a demand is registered are shown on Figure F-1. When queing takes place, there are no arrangements for assigning priority according to length of waiting time or adherence to schedule.

Proposed Improvements

Because of the conflicts inherent in an at-grade junction and the effects of factors other than signaling, the benefits of improved signaling would be only marginal. In view of the acutely congested conditions that exist, however, even marginal improvements would be worthwhile.

The proposed signaling re-arrangement shown on Figure F-2 is intended only to illustrate one possible approach to the problem; more intensive study would be necessary to determine optimum signal positioning in relation to vehicle performance curves and speed restrictions imposed by curvature.

Where positive signal protection exists, an essential prelude to any scheme for improved operation would be the abandonment of the rule which requires a car operator to stop before moving over a facing switch. No sacrifice of safety would be involved, since this safety factor is inherent in a properly designed interlocking system.

It would be desirable also to relieve the operator of the need to consciously select his route at a specific point close to the junction facing switch. The recommended method of achieving the proper selection would be to provide a trackside device to register a claim. The automatic device, located two blocks in advance of the signal protecting junction, would be interfaced with a destination sign and would hold the selection as long as cars or trains were on the same route.

As an example (See Figure F-2), a westbound train might start from Copley Station after the previous train had passed beyond the junction ahead. Signal 822 would be showing green. On passing the signal, a demand for the junction would register automatically without action on the part of the operator. If there were no conflicting movements, the junction would set immediately and, if the straight route had been called for, signals A822 and R2 would display appropriate proceed aspects. If the diverging route had been called for, the clearance of signal R2 would be delayed until the speed of the approaching train had been reduced to a value at which it could safely negotiate the turnout. At this point a yellow aspect, supplemented by a diagonal lunar white light unit to indicate the divergence, would be displayed on signal R2. If conflicting movements had preempted the junction, the train would move up close to signal R2, and the demand would be stored until the route was clear. Then the switches would operate and the signal would show "proceed".

For eastbound trains, where no route selection is involved, demand would be registered by track circuit occupancy at locations shown on Figure F-2 and ACI equipment. If there were no conflict, the route would set and the signals would show an aspect appropriate to conditions ahead. If the train ahead were at correct headway spacing or greater, the rear train would proceed under green signals and thus clear the junction with minimal delay.

If a conflicting movement had preempted the route, the demand would be stored, and the train would proceed to the protecting signal (LA4) and wait. Immediately after the junction had been cleared by an opposing move, or the overlap of signal 821 had cleared, signal LA4 would display "proceed" and the train could move.

Effects of Improvements

The first effect of placing the demand point at a greater distance from the junction would be to eliminate delay when no conflict existed. This benefit would apply particularly to westbound movements in the Boylston Street Subway. The second effect would be to reduce waiting time without coming to a stop. Demands would be entered early enough so that, if they could not be granted, the train could continue to move toward the junction with the assurance that, in most cases, the conflicting movements would be cleared while the train was in motion.

Careful application of modern circuit design techniques and principles would ensure selection of the optimum solution, with a minimum of overall delay at all times.

A full evaluation of time saved under the most adverse conditions would require a more detailed check of existing running times and de-

lays. Formulation of a computer program based on rolling stock and physical characteristics would be required to select optimum signal positions.

Costs

Preliminary estimates based on 1969 levels indicate that the proposed modifications at Copley Junction would cost from $120,000 to $150,000 for fixed equipment, with additional costs for car-mounted equipment.

It would be possible to gain some of the advantages at lower cost. Instead of providing automatic controls, the existing method of junction selection for westbound trains could be retained. Conditions could be improved by moving the selection point to that shown on Figure F-2 and making other signaling modifications shown on that plan and described above. This would preclude the need for car-mounted equipment, but would require action by the car operator at the selection point. This method of route selection is not recommended.

For an expenditure of about $780,000 for wayside and car-carried equipment, all regularly used Green Line subway junctions could be equipped for automatic routing and higher speed operation.

If such an investment is deemed worthy of consideration, further studies should be conducted--for Copley Junction in particular--to estimate more accurately the service benefits that might be anticipated from the improvements. Such studies should include recording and analyzing present running times and delays, calculating and testing by means of a computer the modified service pattern expected to result from the proposed changes, evaluating the results, and making recommendations.

This work should form part of a more extensive study to consider other ways of improving existing Green Line service. Methods might include:

- Expediting passenger loading and unloading during peak hours at the busiest Central Area stations by posting more explicit signs and by using public address equipment and television surveillance cameras for crowd control. The automatic route-selection equipment described earlier could also be used to operate illuminated platform signs; these would give advance warning to passengers of the destination of the next train to arrive and would program the train movements through junctions.

- Applying traffic engineering measures to segregate, or give priority to, streetcars operating in mixed traffic on surface

streets. Where streetcars run on surface tracks in highway medians, conflicts with cross traffic at intersections could be minimized by installing special controls in conjunction with existing street traffic signals, or by providing new traffic signals, to give preference to streetcar traffic. (See Commonwealth Avenue.)

Such measures would improve operations in the subways as well as on the surface by minimizing gaps and bunching, and by facilitating adherence to schedules.

COMMONWEALTH AVENUE IMPROVEMENTS

Although purchase of new cars and modernization of signal equipment would improve service on Green Line subway sections, benefits would not be fully realized if surface route delays and irregular running times continued. These problems are caused by conflicts between rail vehicles and road traffic along surface streets, at road junctions and at many street intersections.

Where transit vehicles share a street with other vehicles, little can be done to improve operations. Where most of a route lies in the private reservation of a divided street, however, as in the case of Beacon Street and Commonwealth Avenue, operations could be improved. Ideally, transit operation should be completely segregated from street traffic to eliminate mutual interference; rights of way should be upgraded to permit higher running speeds; stops should be rearranged to gain more even spacing; and modern signaling with positive speed controls should be installed.

PCC Car in Cross-Traffic on Commonwealth Avenue

The optimum solution would entail substantial expenditures for grade separations but they have not been considered in this stage. A compromise plan should be sought to achieve significant improvements in service at relatively small capital cost. In any such program, rail traffic must be given preference over rubber-tired traffic where there are conflicts.

Problem areas on the Commonwealth Avenue and Beacon Street routes between the respective subway portals and the terminal loops can be classified as follows:

- Major road junctions which involve conflict between rail routes and several road traffic streams, some of which also include rail junctions. (Packard's Corner and the Chestnut Hill Avenue/Commonwealth Avenue intersections are examples.)

- Major road intersections where through road traffic routes cross the rail lines.

- Minor road intersections where local streets or median crossings intersect the rail lines.

The present peak-hour headway on the Commonwealth Avenue route is four minutes. If trains in opposite directions passed a point every two minutes, and each passage stopped road traffic for 15 seconds, the junction or intersection would be occupied by rail traffic for 15 seconds out of every 120 seconds, or 12.5 percent of the time. The remaining 87.5 percent would be available for road or pedestrian traffic.

Recommended Improvements

Major Road Junctions (for example, Packard's Corner and Chestnut Hill Avenue). See Figure F-3. Major alterations to both highway layout and rail tracks should be made to ensure maximum reserved rail-transit area and minimum shared area.

Left-turn movements of vehicular traffic should be carefully considered. Traffic signals should be relocated if necessary to suit new road configurations and controlled so that trains can preempt the right of passage after a safe clearance interval.

Rail passenger pick up points should be placed at the approach to junctions in most cases. Claim by a train for the right to pass through an intersection should be delayed until after passengers had boarded; the train would then move forward, and a special rail contact would actuate the traffic signal. A signal phase for exclusive use of rail transit operations would be incorporated in the timing cycle.

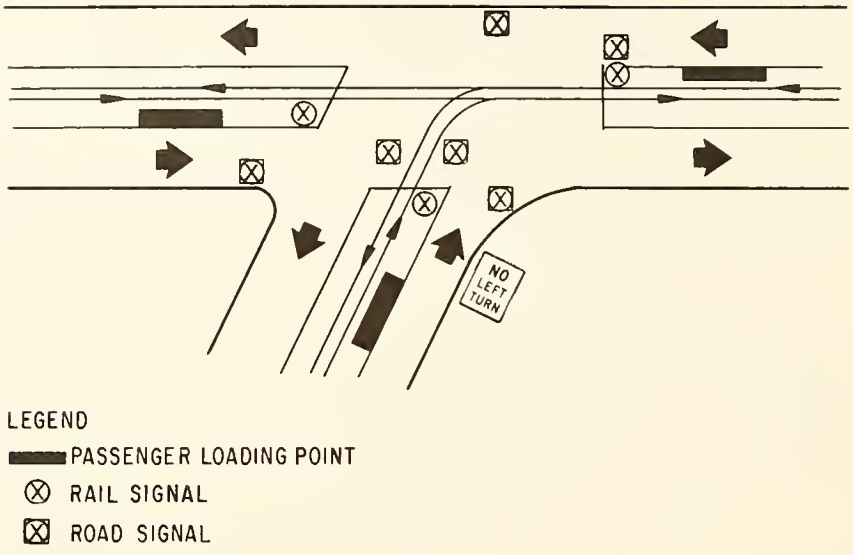


Figure F-3

SEGREGATION OF ROAD AND RAIL TRACKS AT MAJOR JUNCTIONS

Major Road Intersections (for example, Washington Street). See Figure F-4. Road vehicles waiting to turn should be prevented from blocking the rail tracks by appropriate channelization and other traffic engineering measures. Where turning road traffic cannot be prohibited, a special left-hand lane signaled separately for such traffic should be provided.

The reserved rail area should be defined to confine conflicts to the smallest area possible. Rail-passenger boarding points should be relocated to the approach side of intersections. Road signal controllers should be modified to give priority to trains whenever a claim is registered through the operation of a rail contact. Rail signals should be provided for the exclusive use of trains.

Minor Road Intersections. All minor crossings of rail track in medians should be examined in relation to use and to the availability of alternative access to the highway. Unimportant crossings should be closed. Where they must be retained, road signals should be installed to govern movements across the tracks. Signals should be controlled automatically by means of rail contactors to ensure priority for trains and allow them to pass without stopping.

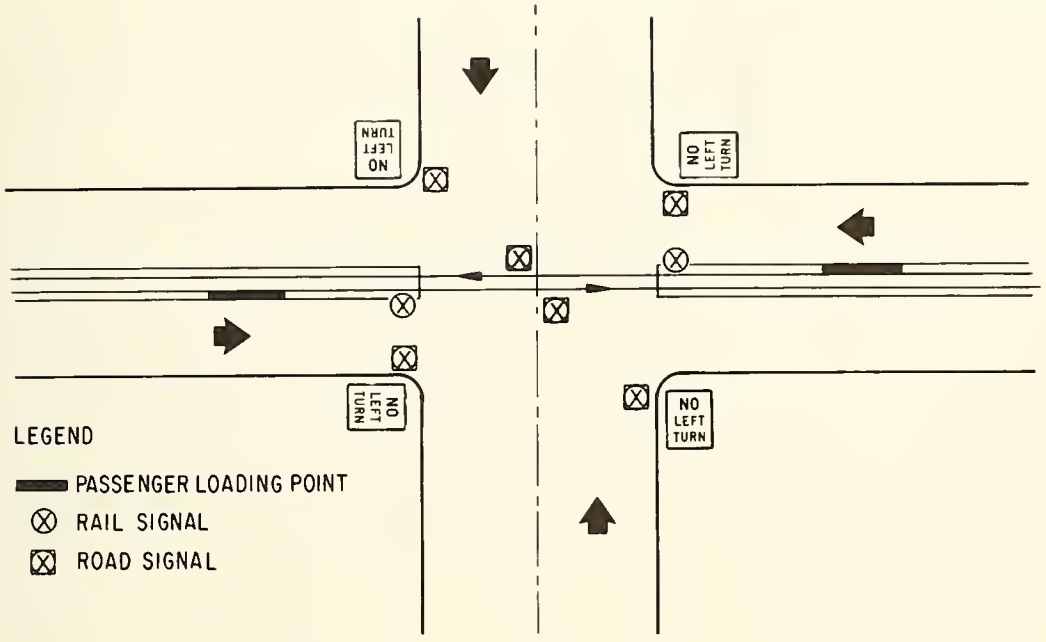


Figure F-4

MAJOR ROAD INTERSECTION

Conclusions

In defining the term "Rapid Transit Rail System", one of the basic conditions is that the system to which the term is applied shall be completely grade-separated. Without full grade separation, the desired objective--fast, dependable, high-capacity service--cannot be assured.

However, partial benefits could be realized through the changes recommended for immediate implementation. This would involve a compromise in which the flow of highway traffic would be hampered to some extent, but delays to transit vehicles would be reduced and trains would be protected by a minimum warning system at intersections (Figure F-5). Although the scheme would not protect trains completely, it would minimize delays of vehicular traffic.

Analyses of delays and their causes are closely associated with highway traffic engineering problems. Eliminating delays of a traffic nature would require the cooperation of all municipalities involved.

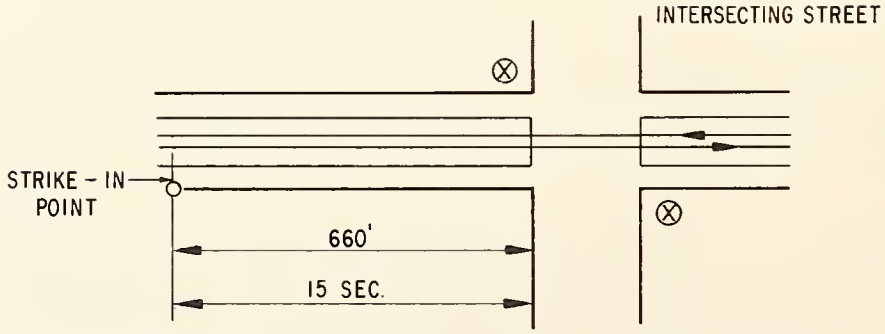
To determine whether installation of a minimum warning protection system would justify the investment, it is recommended that a test sec-

tion of track approximately one mile long including a typical intersection be equipped with the proposed devices and its operation evaluated over a one-year period. Such an experiment could be carried out for between $150,000 and $200,000.

In the more complicated situations investigated, detectors and rail signals or half-barriers might be required to safeguard the trains, but they would impose longer delays on vehicular traffic.

If the experiment described above were successful and the conflict between road and rail traffic were reduced substantially, it would be worthwhile to extend to surface routes the automatic speed-regulation signaling system suggested for the subway together with the proposed new cars, particularly since the cars would be furnished with the necessary equipment. In addition to increasing the safety and efficiency of operation on these surface sections, enlargement of the areas supervised from Central Control and provision of automatic dispatcher schedule control would improve adherence to schedules. Corrective measures in emergency could also be taken more promptly.

It is recommended that a complete study be undertaken for Commonwealth and Huntington Avenues similar to the 1969 study entitled "Surface Car Line Operations Study--Beacon Street-Green Line".



STREET TRAFFIC SIGNALS
5 SEC. MIN. GREEN
5 SEC. AMBER
5 SEC. RED
⊗ RAIL SIGNAL

STREET TRAFFIC DELAY:

RED SIGNAL	5 SECONDS
OVER CROSSING	4 SECONDS
OPERATING TIME	10 SECONDS
TOTAL TIME	19 SECONDS

Figure F-5
MINIMUM WARNING PROTECTION AT INTERSECTION

ESTIMATED COST OF EQUIPPING THE TWO TYPES OF PCC CARS WITH CAR-BORNE SIGNAL EQUIPMENT

Material

The car-borne equipment for each new Type B double-ended No. 6 cars would consist of one electronic and relay logic box, two aspect display units, two sets of pickup coil equipment, one speed sensor, and wire and miscellaneous items needed for a complete installation.

Every one of the PCC cars of both types and the Type A No. 6 cars would be equipped with one aspect display unit and one set of pickup coil equipment, one electronic and relay logic box, and one speed sensor. Some valves and piping would be required for the PCC cars with air brake systems. The cost of PCC car-borne signal equipment is estimated at $6,000 per car.

Labor

Installation of the cab signal equipment on both types of PCC cars is estimated to take 230 man-hours per car. The MBTA electrician's hourly wage rate is $6.50 plus 34 percent for fringe benefits. This is understood to be the highest rate of the various crafts that would participate in the work. The cost of labor for installation, therefore, would be approximately 230 x ($6.50 + $2.21) = $2,000.

The labor cost estimate of $2,000 assumes that cab signal equipment would be installed while cars were in the shop for routine inspection.

Should the cab signal equipment be installed under contract, the estimated cost per car would be $3,000, and groups of cars would have to be taken out of service to permit the contractor to perform the work on a production basis.

Summary

Total cost of equipping both types of PCC cars with cab signal equipment is estimated at $8,000 per car.

When the PCC cars were retired, cab signal equipment could be removed and installed on new cars. The estimated salvage value of the equipment would be $5,000. Salvageable items would include everything except the interconnecting wire and possibly the pickup coil brackets. The original labor cost of installing the equipment, of course, could not be recouped.

Material prices and labor rates used in estimating the cost were based on 1969 levels. The figures would be escalated with any increases after 1969.

DETERMINATION OF THEORETICAL HEADWAY FOR CENTRAL SUBWAY

A typical signal block layout shows that a headway of 60 seconds would theoretically be possible in the Central Subway for trains operating at 40 miles per hour. Such headways would also be possible at junctions since train clearance time plus equipment operating time would be equal to station dwell time.

To help attain the minimum desired headway, an automatic train dispatching system is proposed in connection with signal modernization. Such a system would promote the regularity of service that a headway of 60 seconds requires. It would also preclude the bunching of cars that now prevails. By regulating the trains, this system would allow a more even distribution of passengers and would correct the present excessively long station stops.

The criteria used to determine the minimum headway are as follows:

- Acceleration rate = 3.0 miles per hour per second,
  = 4.4 feet per second per second.
- Deceleration rate = 3.0 miles per hour per second.
- Station dwell time = 30 seconds.
- Reaction time = 2.5 seconds. This would forestall brake application after the operator received signal command. Together with three seconds for equipment operating time, total reaction time would be 5.5 seconds. A four-car train would be about 200 feet long.
- Reaction distance at 40 mph = 58.8 fps x 5.5 seconds = 323 feet.
- Reaction distance at 25 mph = 36.8 fps x 5.5 seconds = 202 feet.
- Acceleration from 0 to 25 mph would cover 250 feet and take 9.5 seconds.
- Deceleration from 40 mph to 25 mph would cover 239 feet and take 5.0 seconds.
- Deceleration from 25 mph to 0 mph would cover 153 feet and take 8.3 seconds.

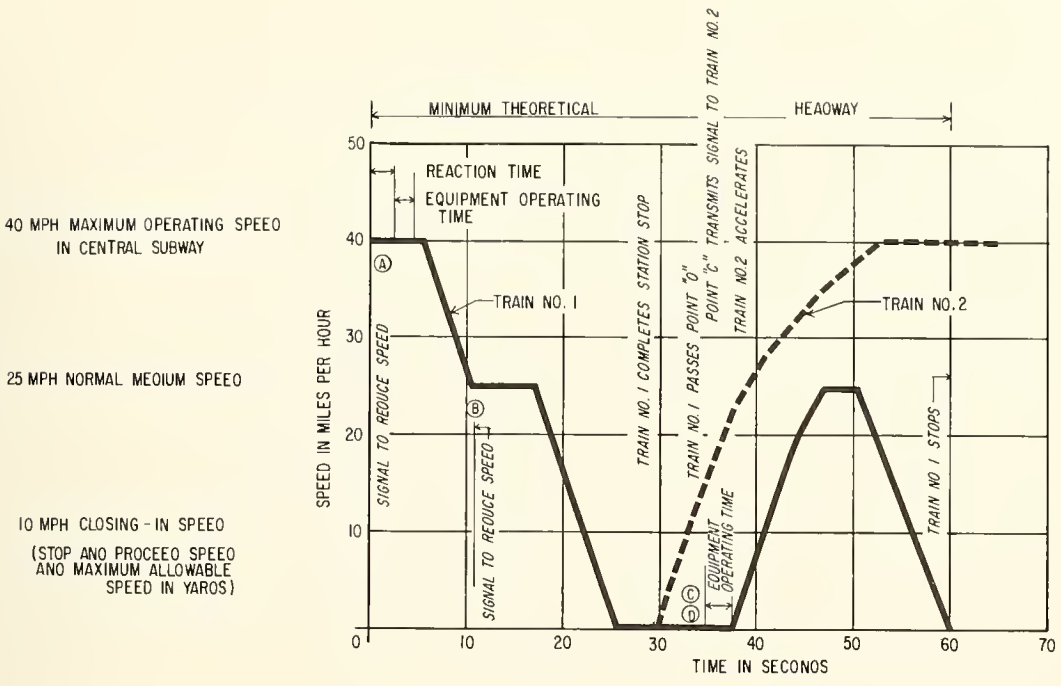


Figure F-6

MINIMUM THEORETICAL HEADWAY OF NO. 6 CAR IN CENTRAL SUBWAY

Minimum headway between consecutive trains approaching and leaving a typical station are shown on Figure F-6. As Train No. 1 stopped at the station and Train No. 2 reached Point A, the following sequence would take place:

- Reaction distance of Train No. 2 at 40 mph would cover 323 feet and take 5.5 seconds.
- Deceleration from 40 mph to 25 mph would cover 239 feet and take 5.0 seconds.
- Operation at 25 mph would continue for 48 feet and take 1.3 seconds.
- Reaction distance at 25 mph would cover 202 feet and take 5.5 seconds.
- Deceleration from 25 mph to 0 mph would cover 153 feet and take 8.3 seconds.
- Train No. 2 would stop and wait until Train No. 1 completed its station stop. This would represent 0 feet and 4.4 seconds.
- Train No. 2 would travel a total distance of 965 feet in 30.0 seconds.

Train No. 1 would finish a 30-second station stop and would begin to accelerate. When the rear of Train No. 1 would pass Point D, Point C would begin to transmit 25 mph code, allowing Train No. 2 to move, and the following steps would occur:

- Train No. 1 would travel 47 feet and take 4.7 seconds, while Train No. 2 waits.
- Train No. 2 equipment operating time would represent 0 feet and 3.0 seconds.
- Acceleration of Train No. 2 from standstill to 25 mph would cover 250 feet and take 9.5 seconds (assuming Train No. 1 continues to accelerate.)
- Operation at 25 mph would continue for 134 feet and take 3.7 seconds.
- Deceleration from 25 mph to 0 mph for a station stop would cover 153 feet and take 8.3 seconds.
- Train No. 2 total distance and time = 1,502 feet and 59.2 seconds.

It is, therefore, shown to be possible for trains to operate through the Central Subway at 60-second headways and achieve a maximum speed of 40 miles per hour.